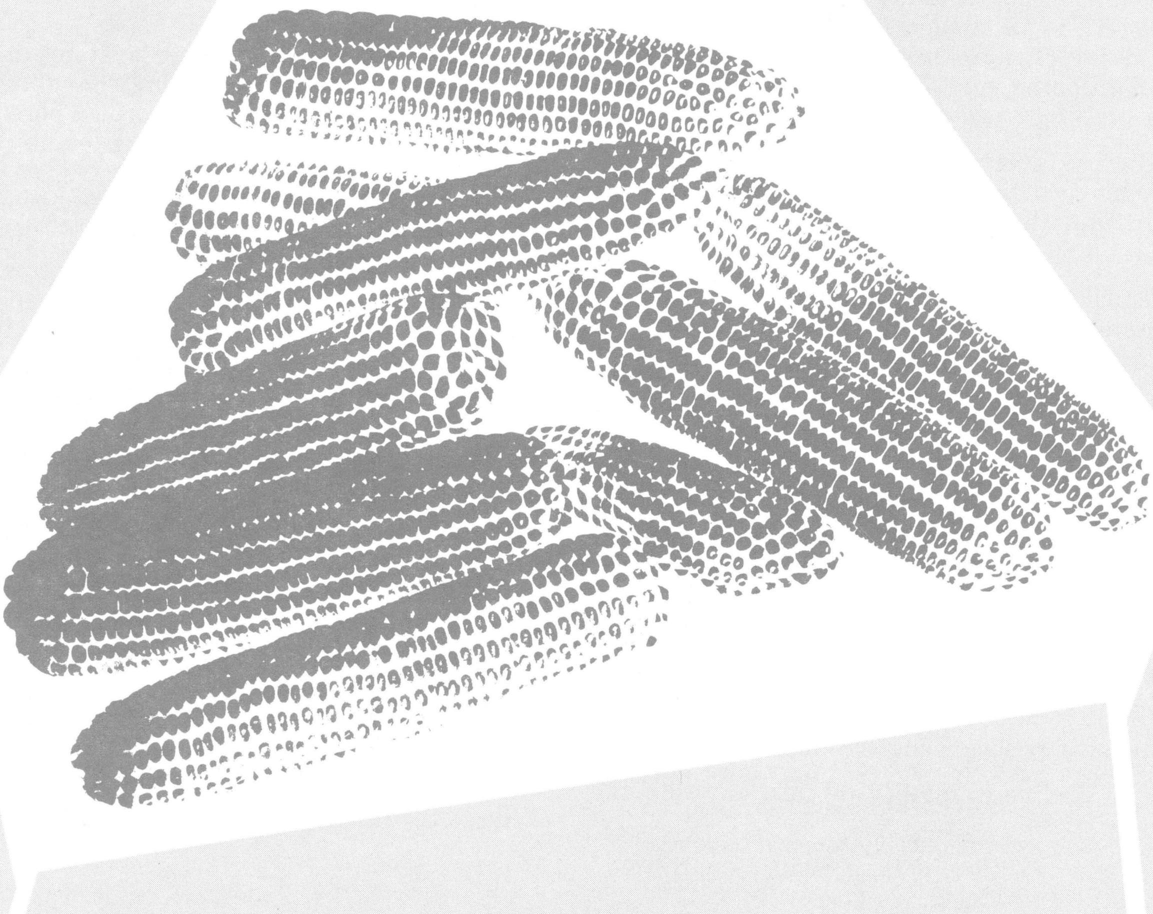
BULLETIN 502

corn / HARVESTING HANDLING MARKETING IN OHIO



COOPERATIVE EXTENSION SERVICE
THE OHIO STATE UNIVERSITY

CORN IN OHIO

Corn is Ohio's most important crop when measured in terms of value of annual production. Average annual value of corn harvested in Ohio during the five-year period 1963-67 was about $265,000,000. When fed to livestock, on the farm where it was produced or elsewhere throughout the area in which Ohio's cash corn crop is marketed, this value was increased much beyond its original market value. In terms of bushels sold from Ohio farms, corn sales now exceed the combined sales of wheat, soybeans, and oats.

Both the on-farm and off-farm phases of Ohio's corn industry are experiencing rapid and significant changes. Statewide per-acre yields have increased from an average of 57 bushels during the five-year period, 1953-57, to 76 bushels in the five-year period, 1963-67. Major changes in methods of harvesting, storing, conditioning, and distributing corn also have occurred.

Of the many spectacular changes that have occurred in the corn industry in Ohio, none has been more significant than those indicated by the following trends:

1. Tremendous increase in total production, in volume produced by each farmer, and in percentage of the crop sold off the farm.
2. Great increase in the amount of corn harvested at kernel moistures higher than 25 percent.
3. Rapid change from harvesting ear corn to field shelling. This change has resulted in greater ease and convenience in handling the crop, but it has created new and serious problems.
4. More on-the-farm drying, storing, and processing of corn.
5. Intensive replacement of labor with capital.
6. Rapid decline in quality of corn entering the grain trade.

People who deal with corn — either as a growing crop or as a product to be fed to livestock or moved about in trade channels — are constantly challenged by these changes in the corn industry. Many decisions must be made about corn in such a changing situation.

This publication is limited to a discussion of corn harvesting, handling, and marketing. It should be recognized, however, that these activities must be built on a corn production system. Normal weather patterns, planting dates, and other factors relating to growing corn should also receive close attention from farmers who expect to improve efficiency in producing, harvesting, and marketing corn. Also it is wise to think of the probable final use of the corn crop before planting.

Most useful corn handling systems involve the functions of harvesting, drying, handling, storing, processing, and marketing of corn. There are many vital questions to be answered in planning for the design and development of a new system or the revision of an existing system. The following considerations are basic to all systems:

1. What use will be made of the corn? Will it be sold as cash grain? If it is to be fed to livestock, what kind of livestock? What quality is needed?
2. What is the average weather risk during the harvest season, and what should be the planned harvest rate to minimize this risk?
3. What are the advantages and disadvantages of the existing system of harvesting, handling, and storing corn? What is the salvage value of the existing system?
4. What improvement in crop handling can be provided by a new system or the revision of an existing system?
5. What investment will be required in a new system? Is adequate financing available?

This publication contains much information with respect to these questions.

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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture. Roy M. Kottman, Director of Cooperative Extension Service, The Ohio State University.

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By ROSS MILNER, Extension specialist in grain marketing

This section explains many facts relating to market demands for Ohio corn and how Ohio's cash corn crop is marketed and distributed. Various alternatives available to corn growers for marketing their grain are discussed, and the consequences of choosing some of the alternatives are analyzed.

SECTION 2. HARVESTING, CONDITIONING, AND STORAGE

By W. R. SCHNUG, Extension agricultural engineer, farm electrification, and
D. M. BYG, Extension agricultural engineer, farm machinery

Harvesting and storage methods are explored in this section, and several alternatives available to corn growers—whether they expect to feed their corn crop to livestock or sell it as cash grain—are described.

SECTION 3. MANAGEMENT CONSIDERATIONS

By R. DONALD MOORE, area agent, farm management, Eaton Area Extension Center

This section explores management decisions farmers must make about the various alternative harvesting and handling methods as they relate to specific needs.

Although this publication, no doubt, will be more useful to farmers who face choices of harvesting and handling methods relating to corn, people involved in all other phases of the corn industry will also find the information useful.

Numerous other research and Extension Service publications that deal with various phases of the corn enterprise in Ohio are available in county and area offices of the Cooperative Extension Service. Some of the more recent and useful publications relating to corn production, harvesting, handling, marketing, distribution, and utilization are listed on page 32.

SECTION 1. CORN MARKETING AND DISTRIBUTION

By ROSS MILNER, Extension specialist in grain marketing

Demand for Ohio Corn

Among the major corn-producing states, Ohio lies closest to the feed grain deficit areas of the Northeast, East, and Southeast. The 14 states — Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Rhode Island, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, and North Carolina — feed more grain than they produce. For example, in 1966 these state produced only 6.75 bushels of corn for grain for each grain-consuming animal unit, whereas Ohio produced 43 bushels.[1]

In 1966, the 14 states produced 6,010,000 tons of feed grains but fed 16,666,000 tons, thus requiring the purchase of 10,656,000 tons of feed grains from other states.[2] Figure 1 shows that, geographically, Ohio is ideally located to supply corn to these 14 states which are indicated as "Ohio's Primary Market."

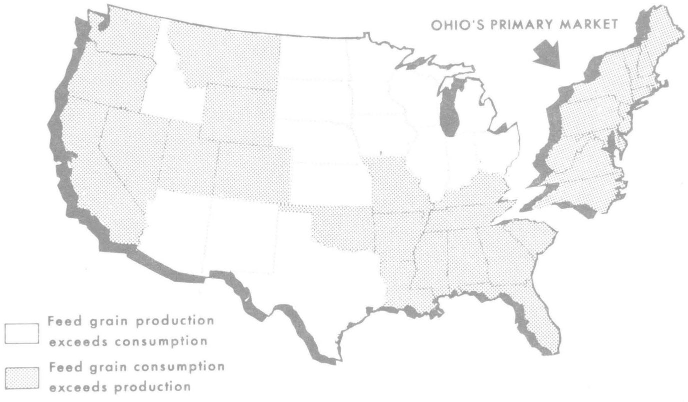
Recently established point-to-point rail rates on corn, which increase on a per-bushel basis as mileage increases, have increased the competitive advantage of states like Ohio that are located close to consuming markets. Corn produced in Ohio also moves in export from lake ports and eastern ports. In 1967, the port of Toledo exported 22,845,000 bushels of corn that originated in Ohio, Indiana, and Michigan. There is no breakdown in the records as to quantities from each state.

Corn for domestic use usually commands a higher price than for export. Because of Ohio's comparative advantage in shipping to the relatively high priced domestic market of eastern United States, most of the state's corn sales are made in that area.

The expansion of highways and motor carrier use and the introduction of point-to-point rail rates in 1964 have improved Ohio's competitive relationship with other corn-shipping states. Despite this favorable opportunity to serve the Eastern States, however, the Ohio grain industry is not necessarily assured of this market in the future. The Ohio corn industry, including both farmers and wholesalers, must provide corn when it is wanted, in the volume desired, and of the grade and quality demanded. The term "demanded," as used here, refers to the grade and quality which buyers want and are willing and able to pay for.

Although point-to-point rail rates have resulted in lower charges for transportation as distance decreases, they have also caused disruption in grading

FIGURE 1—U. S. Feed Grain Production and Consumption Balance in 1966 and Ohio's Primary Corn Market



Source: Livestock-Feed Relationships, Statistical Bulletin No. 337, Supplement. Economic Research Service, USDA, November, 1967

and other practices. Since grade standards were established in 1916, corn has been graded at terminal origin points by inspectors licensed by the Federal Government. With point-to-point rates, corn often does not move through terminal origin points and, therefore, is not graded by licensed inspectors before it reaches destination points. Also, it is generally not graded by inspectors even at such points. The present situation is less satisfactory to eastern buyers, and remains, at this time, an important problem to be solved.

Cost reductions in transporting grain on point-to-point rates arise from larger scale movements, fewer switchings, and less inactive time of rail cars during loading and unloading. Methods of increasing the size of shipment at reduced charges per bushel transported include larger car capacity and the use of multiple cars in one shipment from one origin point to one destination point. In some areas of the grain belt, still larger single shipments consist of unit trains and "rent-a-train" arrangements in which the entire cargo consists of corn to be unloaded at only one point. Although Ohio can participate in cost advantages arising from larger single shipments, the practice is best adapted to areas of highest concentration of corn production per square mile such as in Illinois. This level of production provides a relatively large supply of near-by corn for loading. Thus, Ohio has an ideal location, but the industry in Ohio must meet the demands of eastern buyers if the state is to remain a principal supplier of this market.

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1 Supplement for 1967 to Livestock-Feed Relationships 1903-68. Statistical Bulletin No. 337 (Supp.). Economic Research Service, USDA

2 Same

Ohio's Commercial Corn Supply

Sales of corn in Ohio have been increasing as shown in Table 1.

TABLE 1—Ohio Production and Sales of Corn
(In Millions of Bushels)

Time Period	Production	Sales	Percent Sold
1949 - 53	174	52	30
1954 - 58	194	81	42
1959 - 63	213	91	43
1964	192	81	42
1965	226	108	48
1966	262	136	52
1967	256	141	55

Source: Crop Reporting Board, Statistical Reporting Service USDA

It is estimated that in 1966 Ohio farmers received $177 million from the sale of corn. This amounted to more than 13.5 percent of the total estimated cash receipts of $1,301,819,000 received by Ohio farmers.

Table 2 shows the volume of production and sales of corn by the 10 leading states in 1967.

TABLE 2—Ten Leading States in Production of Corn for Grain and Sales—1967

States	Thousand Bushels Production	Sales
Illinois	1,091,500	753,135
Iowa	930,155	399,967
Indiana	447,804	277,638
Minnesota	355,896	153,035
Nebraska	329,230	184,369
Ohio	255,960	140,778
Missouri	198,168	81,249
Wisconsin	136,240	32,698
North Carolina	107,160	62,153
Kentucky	93,440	36,442
Total U.S.	4,722,164	2,496,137

Source: Field and Seed Corps, Cr Pr (67) Crop Reporting Board, Statistical Reporting Service USDA, May 1967

Seasonal Corn Price Changes

In the average year, the Ohio price of No. 2 yellow corn increases about 12 cents per bushel from harvest time to mid-May. In some communities, the margin taken by country elevators is two or three cents larger at harvest time than later in the season. In such communities, the seasonal increase in price to farmers amounts to 14 on 15 cents per bushel in the average year. These average seasonal price increases, however, are made up of highly variable annual seasonal price changes. Monthly cash market price changes for the last 10 years (shown in Table 3) disclose that seasonal prices increased as little as 2 cents in 1966-67 to as much as 19 cents in 1964-65. Thus, the annual compensation for storing corn is variable and unpredictable.

May futures corn prices are also shown in Table 3 alongside the cash market prices. Futures prices increased seasonally on the average, but by a much smaller amount. This reflects the fact that it costs more to hold the actual corn than to hold corn futures.

Selling Corn at Harvest and Buying Futures

Many farmers want to know the economic feasibility of selling corn at harvest time, thereby eliminating the risks and costs of actually storing the corn but, at the same time, profiting by an anticipated rise in corn futures prices. Prices of cash corn and Chicago May futures as shown in Table 3 provide an opportunity to make a general analysis of this practice.

Futures prices increased seasonally in only 6 of the last 10 years shown with an average seasonal increase of 3 cents per bushel. Costs of trading in futures are a little less than 1 cent per bushel, hence the average net profit, after including an interest allowance on the use of margin money, averages a little over 2 cents per bushel.

How to Establish Corn Prices Before Harvest

At a cost of 1 cent or less per bushel, a farmer can establish the approximate price he will receive for his corn long before harvest. This is accomplished by selling December futures contracts and is possible because, at harvest time, farm prices and December futures contract prices have a fairly predictable relationship. The farm price of corn in western and central Ohio at harvest time averages about 13 cents per bushel below the December corn futures price at that time. It is fortunate that this close relationship exists because you, as a corn farmer, can establish a net price for your corn months ahead of harvest time if you choose to do so. Of course, no one should establish a price in advance of harvest unless he thinks he is "making a good sale."

Setting a price is initiated by selling December futures contracts. To illustrate the practice, let us assume that on a given day in the spring, the corn futures price for the following December is trading at $1.40 per bushel. You recall that at harvest time during the last few years the price at western and central Ohio elevators has been about 13 cents less than the Chicago December futures. This means that by selling December futures, you can establish a net price of about $1.26 — that is, $1.40 minus 13 cents, minus a 1-cent cost per bushel to trade in futures. Assume, also, that you believe $1.26 is as high as, if not higher than, you can net between now and harvest. So you can assure yourself of this net price ($1.26) by selling December futures contracts at $1.40. You complete your marketing activities at harvest time by delivering your crop of corn to your local elevator and, at the same time, you buy back your December futures contract or contracts.

Your net price will be about $1.26 whether the December futures price rises or falls. To prove this, observe that if the December futures price should rise, for instance, to $1.50 at harvest time, the loss

TABLE 3—Seasonal Corn Prices 1957-1967

(Cash Prices Bid F.O.B. to Country Elevators in Central Ohio and May Corn Futures Prices, Chicago; All Prices at Mid-Month [a]

Year	October [b] Cash	October [b] Fut.	November Cash	November Fut.	December Cash	December Fut.	January Cash	January Fut.	February Cash	February Fut.	March Cash	March Fut.	April Cash	April Fut.	May Cash	May Fut.
1957-58	1.16	1.27	1.18	1.26	1.17	1.22	1.14	1.16	1.14	1.14	1.18	1.16	1.31	1.27	1.29	1.28
1958-59	1.17	1.19	1.11	1.19	1.17	1.17	1.17	1.15	1.18	1.17	1.21	1.19	1.29	1.26	1.27	1.27
1959-60	1.03	1.16	1.09	1.19	1.09	1.17	1.14	1.18	1.13	1.17	1.16	1.17	1.20	1.19	1.19	1.19
1960-61	1.03	1.15	.93	1.12	1.02	1.13	1.09	1.16	1.14	1.20	1.14	1.18	1.07	1.09	1.13	1.15
1961-62	1.06	1.19	1.09	1.18	1.11	1.14	1.07	1.11	1.07	1.10	1.10	1.11	1.12	1.11	1.15	1.12
Ave: Cash	**1.09**		**1.08**		**1.11**		**1.12**		**1.13**		**1.16**		**1.20**		**1.21**	
Ave: Futures		**1.19**		**1.19**		**1.17**		**1.15**		**1.16**		**1.16**		**1.18**		**1.20**
1962-63	1.05	1.11	1.08	1.12	1.13	1.14	1.17	1.17	1.20	1.19	1.19	1.18	1.19	1.17	1.22	1.21
1963-64	1.17	1.25	1.13	1.24	1.20	1.23	1.23	1.23	1.19	1.21	1.22	1.22	1.24	1.23	1.24	1.24
1964-65	1.18	1.27	1.16	1.27	1.25	1.29	1.25	1.29	1.26	1.30	1.30	1.32	1.33	1.33	1.37	1.35
1965-66	1.11	1.22	1.15	1.23	1.25	1.29	1.30	1.32	1.30	1.30	1.25	1.24	1.27	1.27	1.28	1.27
1966-67	1.32	1.42	1.34	1.49	1.40	1.47	1.33	1.42	1.32	1.38	1.38	1.43	1.33	1.37	1.34	1.32
Ave: Cash	**1.17**		**1.17**		**1.25**		**1.26**		**1.25**		**1.27**		**1.27**		**1.29**	
Ave: Futures		**1.25**		**1.27**		**1.28**		**1.29**		**1.28**		**1.28**		**1.27**		**1.28**

[a] Cash prices are transit rate bids through March 1965, thereafter mileage rate bids. The latter ranges from 0 to 3 cents higher than transit rate bids.

[b] Cash prices of old and new corn for immediate delivery on October 15, 1958 were the same. For later delivery, the cash price on October 15, 1958, was $1.05. Immediate demand for corn at the end of the marketing season tends to frustrate pricing. Farm prices may be derived by subtracting the country elevator margin from the above cash prices.

Sources: Future prices from Board of Trade, Chicago. Cash prices from the Grain Division, Ohio Farm Bureau Cooperative Association, Inc., Columbus, Ohio

on the futures trading will be 10 cents per bushel, but the price of your corn at the elevator can also be expected to have risen 10 cents. The net price will, therefore, be $1.26. On the other hand, if the December futures price should drop to $1.30 at harvest time, the gain in trading in futures will be 10 cents per bushel. But the price of your corn at the elevator will be expected to have dropped 10 cents. Again, the net price will be $1.26.

December corn futures prices are seldom at their peak at harvest time. Considering only prices on the last trading day of each month, Table 4 shows that from 1959 to 1967 prices of the next crop were usually highest before corn harvest and often even before planting time. October and November harvest-time prices are often several cents per bushel below earlier prices.

The figure also illustrates years in which producers would likely not see fit to establish a price before harvest time because there was no apparent opportunity to "make a good sale." One such year was 1963 in which there was little change in price from January to harvest time.

It should be observed that if you store your corn, you have the opportunity of choosing whether or not to accept each day's price during several months after harvest. Also, since December futures contracts are traded daily from the preceding January, you have the opportunity of choosing whether to accept each day's net price from that time until you dispose of the corn at harvest. And lastly, if you simply sell on the day you deliver your corn to the elevator at harvest, you must accept whatever price is offered that particular day.

TABLE 4 — December Corn Futures Prices

Chicago Board of Trade Closing Prices on Last Trading Day of Each Month [a]

	1967	1966	1965	1964	1963	1962	1961	1960	1959
	Cents per Bushel								
January	133	122	120	119	114	116	122	110	108
February	137	119	121	121	115	116	119	111	114
March	142	120	121	120	114	119	115	111	115
April	136	121	122	119	114	118	121	111	116
May	136	124	119	118	116	116	122	113	114
June	130	139	121	118	118	113	121	112	115
July	121	144	120	114	113	109	117	112	114
August	118	146	118	121	113	107	114	110	112
Sept.	114	138	117	121	120	107	109	109	110
October	114	138	114	119	117	107	108	108	110
Nov.	114	140	118	123	116	108	110	103	110
Dec. [b]	115	142	123	124	119	112	108	104	108

[a] Fractions of one-half or over are raised to the next whole number; under one-half, they are dropped.

[b] With December futures, the last trading day on the Board of Trade is the eighth day preceding the last business day in December.

Source: Annual Statistics, Board of Trade, Chicago.

Corn Grading and Discounting

Corn standards are established by the U. S. Department of Agriculture. Licensed inspectors who designate official grades also are trained, examined, licensed, and supervised by federal grain supervisors but are paid through boards of trade, chambers of commerce, or directly by buyers and sellers of grain. In some states, they may be employed by agencies of the state governments.

Grades assigned by licensed inspectors may be appealed to federal supervisors who will regrade the grain. An additional fee will be charged unless the original grade was incorrect. Thus, official grain grading is largely financed by the industry but is supervised by the Federal Government.

Official grain standards were first established by Congress in 1916. For many years, there had been a recognized need for national standards. There were sharp differences of opinion, however, over the proper role of government in actual grading and bearing of costs. For example, between 1903 and passage of the act in 1916, some 26 different bills were introduced in Congress.

The 1916 act provides that grain shipped in interstate or foreign commerce from or to a point at which an inspector (licensed under the act) is located, must be graded by a licensed inspector whenever the grain is merchandised by grade.

Official standards have permitted buyers and sellers to trade freely in grain at home and abroad without the need for observing the grain itself. As a result, important savings have been made in marketing costs.

Eventually, the act of 1916 became outmoded due to changes in practices in transporting and storing grain. It was often disregarded by the industry and often not enforced by the government. During the 1960's both the grain industry and the government expressed a desire for changes. These expressions resulted in passage, in 1968, of the U. S. Grain Standards Act which amends the act of 1916.

The amendment deletes the requirement that grain in interstate commerce must be inspected by a licensed inspector. However, no grain which is sold, offered for sale, or consigned for sale for shipment in interstate or foreign commerce, shall be designated by any grade other than that of the official grade designations and then only when inspected by a licensed inspector. With respect to grain shipped in interstate commerce, the use of one or more grade factor designations set forth in the official U.S. Standards for Grain will not be considered to be a description of the grain by grade. Examples of such grade factors are test weight, moisture, broken corn, and foreign material and damaged kernels.

Licensed inspectors are not permitted to be financially interested in any way or to be employees of any firm owning or operating a grain elevator or warehouse or engaged in merchandising of grain, and they may not accept gratuities from any such firms. However, the Secretary of Agriculture may license qualified employees of grain firms to perform official sampling activities with which licensed inspectors will determine the grade.

The new law provides legalized grading alternatives to buyers and sellers in merchandising grain. They may pay the cost and trade on the basis of official sampling and inspection or simply on the statements of the buyer and seller as to grade.

Nearly all the corn that moves by rail from Ohio is transported under a point-to-point tariff. Under such a tariff, grain usually moves in a direct shipment from country points to final points of consumption in eastern markets. Many of these new points of origin do not have nearby services of official grain inspectors. Moreover, point-to-point tariffs do not provide for stops enroute to permit grading. As a result, many Ohio sellers and eastern corn buyers are trading in corn without the use of official grades. It is hoped that the 1968 U.S. Grain Standards Act will aid in solving this problem. Although many regulations are still to be developed by the Secretary of Agriculture before the act becomes fully effective on February 11, 1969, it appears that the amendment which permits the licensing of warehouse employees "to perform official sampling functions" offers, at least, a partial solution the problem.

Also needed is a review of the official standards for corn. One of the factors shown in Table 5 is entitled, "Broken Corn and Foreign Material." It is defined as "kernels and pieces of kernels of corn and all other matter other than corn which remain in the sieved sample."[3] The factor consists of two highly unrelated types of matter as the name implies. Broken corn, however, likely will be used in livestock feed and, for this purpose, it may be similar in value to whole corn. With the increase in field shelling, there is an increase in the percentage of broken corn. Because of the great difference in value of broken corn and foreign material, there is a need to separately show the two materials. Such changes could result in prices which would be based more nearly on the actual value of the corn offered for sale.

The grain industry is responsible for determining and administering whatever premiums and discounts are provided. The industry, however, commonly bases corn buying and selling prices on No. 2 grade. Any premium offered is added to the No. 2 price; any discount is deducted from it. Thus, the grain industry has commonly elected to make use of the official grain standards in arriving at the actual price. Each buyer and seller determines the amounts of whatever premiums and discounts he offers for deviations from the official grades.

Official corn standards, with approximate discounts made by Ohio processors and terminals in buying corn from country elevators, are shown on the following two pages.

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3 Official Grain Standards of the United States SMA-AMS-177, USDA

TABLE 5—Corn Grades

(For All Classes Including Yellow Corn, White Corn and Mixed Corn)
Copy of Official Corn Grades

Grade	Minimum Test Weight Per Bushel	Moisture	Maximum Limits of Broken Corn and Foreign Material	Damaged Kernels Total	Heat-damaged Kernels
	Pounds	Percent	Percent	Percent	Percent
1	56	14.0	2.0	3.0	0.1
2	54	15.5	3.0	5.0	.2
3	52	17.5	4.0	7.0	.5
4	49	20.0	5.0	10.0	1.0
5	46	23.0	7.0	15.0	3.0

Sample grade — Sample grade is corn which does not meet the requirements for any of the grades from No. 1 to No. 5, inclusive; or which contains stones; or which is musty or sour or heating; or which has any commercially objectionable foreign odor; or which is otherwise of distinctly low quality.

SPECIAL GRADES [a]

1. Flint — 95% or more of flint corn.
2. Flint and Dent — A mixture of flint and dent corn with more than 5% but less than 95% of flint corn.
3. "Weevily" — When any one or more of the following conditions (a to e) are found:

	1⅛ to 1¼ quart portion of sample: Live Weevils		1⅛ to 1¼ quart portion of sample: Injurious live insects		Remainder of original sample: Live Weevils		Remainder of original sample: Injurious live insects
(a)	2 or more						
(b)	1			and	1	or	5 or more
(c)	1	and	5 or more				
(d)			15 or more				

(e) A considerable number of live angoumois or other live moths are present in, on, or about the lot of corn — discount 3 cents.

GRADE DESIGNATION — for corn
The specified order of writing the grade designation shall be in the order appearing to wit:

- number of grade or the words "Sample Grade"
- name of the class (example, Yellow Corn)
- name of each applicable special grade

[a] Basically, "Special Grades" serve as amendments to the official grades because they are added to them.

Source: Official Grain Standards of the United States
SRA-AMS-177 Grain Division AMS, USDA
Revised May, 1964

TABLE 6—Corn Grades: Premiums and Discounts

In Ohio, corn prices, premiums, and discounts are usually based on No. 2 Grade. Therefore, this grade is of primary importance in buying and selling.

Grade Factors		Buying Grade No. 2	Approximately Discounts by Processors and Terminals
Test Weight	Min.	54 lbs.	½ to 1 cent each lb. or fraction under 54 lbs.
Moisture	Max.	15.5%	1 to 1½ cents each ½% over 15½%
Broken & F.M. [a]	Max.	3%	1 cent each 1% or fraction over 3%
Total Damage	Max.	5%	½ to 1 cent each 1% or fraction over 5%
Heat Damaged	Max.	0.2%	½ cent each 1/10% over 2/10% to 3% then 1 cent each 1/10%
Additional Grade Factors [b]			(Always SAMPLE GRADE when present)
Inseparable Stones (over 7 stones/1000 grams			Subject to negotiation
Musty			5 to 10 cents or subject to negotiation
Sour			10 cents or subject to negotiation
Heating			5 to 10 cents or subject to negotiation
C.O.F.O. [c]			Subject to negotiation
D.L.Q. [d]			Subject to negotiation or rejection

[a] See explanation below in "Broken Corn and Foreign Material"
[b] Sample grade is described in Table 5
[c] C.O.F.O. — Commercially Objectionable Foreign Odors — includes skunk, smoke, burned, decaying plants and animals, oil, fertilizer, hides, etc.

TABLE 6 — Corn Grades (Continued)

[d] D.L.Q. — Distinctly Low Quality — includes rodent excreta in excess of .2% based on 1⅛ to 1¼ quarts or original sample, stones, pieces of glass and concrete too large to enter the probe, castor beans, cocklebures, Crotalaria more than 2 in 1000 grams and unknown foreign substances or commonly recognized harmful or toxic foreign substances. Also, other unusual conditions which adversely affect the quality and which cannot be properly graded by specified factors.

DAMAGED KERNELS

Determinations are made from approximately 250 grams. In general, damage must be distinctly apparent. Types of damage include heat damaged (materially discolored by heat) slight discoloration by heat (damaged by heat but not materially discolored), blue-eye mold, damaged germ, cob rot, weevil-bored kernels, sprouted, badly ground damaged, badly weather damaged and otherwise materially damaged. When kernels are otherwise sound, slight surface mold and silk cut kernels are considered sound kernels.

BROKEN CORN AND FOREIGN MATERIAL

This factor includes kernels and pieces of kernels of corn and all matter other than corn which will pass readily through a 12/64 sieve and all matter other than corn which remains on the sieve. Sweet corn and popcorn are considered to be broken corn and foreign material.

Source: Discount data from Grain Division, Farm Bureau Cooperative Association, Inc., Columbus, Ohio

Marketing Factors Relating to Local Storage

Point-to-Point Rail Rates Encourage Local Storage

With point-to-point-type rail rates now in effect for shipping corn, it is more profitable to store corn locally. Farmers, country elevators, terminal warehouses, and processors are all affected by the new rates. Storing corn in distant warehouses for eventual reshipment results in higher rail transportation costs than prevail for direct shipments from local storage to final destination.

Point-to-point-type rates were introduced in July, 1964, as an alternative to the existing transit-type rates which have been in effect for many years. The basic differences in these two types of rates are described here so that the reason for the economic importance of storing corn locally may be understood more completely.

The transit-type rail rate structure was initiated about 1900 and is such that the local rate from the point of origin to a massive terminal warehouse is high relative to the rate for reshipping to the consuming market. The reshipping rate from the terminal warehouse to the consuming market is low because it consists of only the through rate minus the local rate as shown in Figure 2. The figure illustrates high local rates from Lima to Toledo and low reshipping rates from Toledo to Baltimore. This type of rate permits grain to move to a distant terminal warehouse for a stop-over, then eventually to the consuming market at the same total change as though it had moved the entire distance in one direct shipment. There is an additional cost to the railroad whenever the grain shipper chooses to direct a shipment to a warehouse or processor with the shipment stopped for storing, milling, grading, etc. Such costs are included in transit-type rates, whether or not all the services are used.

FIGURE 2—Illustration of Transit-Type Rates per Hundredweight on Grain (Single Car)

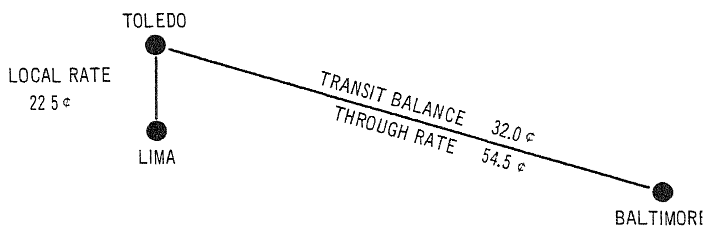


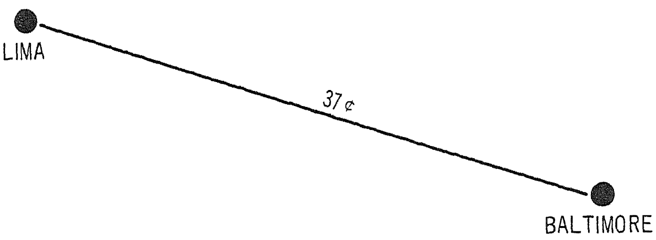
Figure drawn approximately to scale.

Rail distance from Lima to Toledo is about 82 miles; from Toledo to Baltimore, 590 miles. The through rate from Lima to Baltimore is 54.5 cents per cwt. whether the shipment moves directly from Lima or indirectly through Toledo.

Point-to-point-type rates, on the other hand, (illustrated in Figure 3), are based on few services and correspondingly low rates. With such rates, grain moves over the short-line mileage of the various railroads involved from the point of origin to its final destination in one shipment. The rate is based on distance and without built-in costs for services which may not be needed.

The relatively low point-to-point rates normally result in lower total marketing costs, provided the storing and other services are performed at or near the point of production. This means storing either on the farm or at the country elevator, or at both points.

FIGURE 3—Illustration of Point-to-Point Type Rates per Hundredweight on Grain (Single Car)



The rate from Lima to Baltimore is based on the cost of moving corn a distance of 589 rail miles. "Transportation frills" and additional charges for them have been removed.

Grain Car Shortage

Nearly every year there is an acute shortage of freight cars during the peak movement of grain. The demand by the grain industry is greatest during the soybean and corn harvest. Analysis of the causes of the car shortage involves both the supply and demand for railroad freight cars.

Combined sales of corn and soybeans in the United States were 2,908,000,000 bushels in 1966 as compared with 1,684,000,000 bushels in 1956, a 77-percent increase. Although there has been a large increase in the volume of soybeans and corn to be shipped, the rapid shift to field shelling of corn is an even greater cause of the serious peak in demand for grain cars. It is estimated that more than half of the corn in the Corn Belt is harvested by picker-shellers or corn combines. The rapid change in the method of harvesting corn has left many farmers without usable facilities for drying and storing shelled corn. This in turn has caused farmers to deliver large quantities of high-moisture shelled corn to the first receiver at harvest time. Usually the first receiver has too little storage capacity for the increased volume he receives. In response, he attempts to get grain cars and to ship all the grain he can. This chain of events is largely responsible for the increasing grain-car shortage at harvest time.

The demand for railroad cars is also affected by the availability of other types of carriers, such as trucks and barges. Although the total volume of corn shipped by rail is not known, a recent study by the Iowa Agricultural Experiment Station indicated that railroads handled 66 percent of the corn from Iowa while in transport beyond the state borders. This was true even though barge and truck transportation are readily available from Iowa.

Trends in the inventory of railroad cars in which grain is shipped are shown in Table 7. Also shown are trends in the volume of sales of the three principal grain crops.

Both general box cars and covered hopper cars are used in shipping grain. The combined capacity of the two types of cars owned by railroads amounted to 36,092,000 tons in 1956 and 31,959,000 tons in 1966. In addition, nearly 16 percent of all freight cars are privately owned, and they increase the capacity to the evtent that they are available to the grain industry.

The general box car has been the primary type of car available to the grain industry throughout the history of railroads, but it is not well suited for shipping bulk commodities such as grain. The large doors in the center of each side of the car must be closed by using additional supplemental doors each time a grain shipment is made. Loading is difficult because the loading spout can be inserted only in the central area of the car. Unloading of bulk commodities from box cars is also inefficient and costly. The number of covered hopper cars owned by railroads has increased greatly during the last 10 years. Many large grain firms have purchased hopper cars for their own use in order that they will have them when they need them. In 1961, it was estimated that 12 percent of the grain was shipped in covered hopper cars.[4]

With the increase in the number of such cars, it seems certain that the percentage of grain shipped in covered hopper cars has increased since then.

The increasing number of covered hopper cars, however, likely will not be sufficient to meet future demand. The number of different commodities that can be shipped in specialized cars is, of course, more limited. Their usefulness is largely limited to hauling dry bulk commodities. Thus, if the railroads

[4] Marketing and Transportation Situation, USDA Mts-147, 1962.

TABLE 7—Sales of Selected Grains in U. S. and Number of Freight Cars Owned by Class I Railroads in 1956 and 1966

Year	Selected Grain Sales (Million Bushels)			General Box Cars		Covered Hopper Cars	
	Wheat	Corn	Soybeans	Number	Capacity (Thousand Tons)	Number	Capacity (Thousand Tons)
1956	921	1,253	431	673,747	32,839	46,952	3,253
1966	1,242	2,072	908	455,753	23,554	103,477	8,405

Source: "Sales of Selected Grains data from Field and Seed Crops," Crop Reporting Broad, Statistical Reporting Service, USDA Freight car data from "Statistics of Railroads of Class I, Statistical Summary No. 51, Association of American Railroads, August, 1967.

were to build enough specialized cars to accommodate the total demands of grain shippers at the peak of the season there would be little need for many of the cars during the long off-season period. This means that in relation to demand the railroads will, no doubt, plan to have even less car capacity available in relation to demand.

This analysis leads to the growing belief that the best approach to the car shortage problem is to eliminate the peaks in demand for cars. This can more nearly be accomplished by conditioning and storing grain at or near the point of production. Shipments can then be made to processors and exporters as the grain is needed. Since the demand for grain is relatively uniform throughout the year, there would be no need under such a system to have large shipping peak periods.

Corn Price Support Program

The Food and Agricultural Act of 1965 provided for a voluntary feed grain program in the United States for 1966-69 crops. A law, passed in 1968, extends the act to include crops harvested in 1970. During these years, the corn price support is determined by the Secretary of Agriculture at the level between 40 and 90 percent of the parity price, provided there is no acreage diversion program for feed grains. If an acreage diversion is in effect, the support level is to be set between 65 and 90 percent of the parity price.

Government price support loans to farmers are made directly through county offices of the Agricultural Stabilization and Conservation Service or through approved agricultural cooperative marketing associations (or both). Price support loans are nonrecourse. This means that the Commodity Credit Corporation requires only the pledged or mortgaged collateral (the commodity) for settlement of the loan. If a farmer chooses not to repay, CCC takes title to the commodity, and if the commodity is acceptable, the loan (including interest) is satisfied. Such a loan program gives farmers an opportunity to obtain cash and to hold their crops, without market risk, for later sale.

The loan program tends to even out marketings. In order to meet operating costs, farmers would otherwise be inclined to market their crops at harvest time. This sometimes causes market gluts, undue burdening of the transportation system, and lower prices. Price swings and transportation bottlenecks are minimized by spreading commodity marketing over the season.

Producers also can be more independent in their marketing operations and may benefit from price increases which otherwise might not have occurred until after they had sold their products.

On the other hand, whenever the government owns a supply of stored corn, it may be released on the market if the price reaches a prescribed level. Such a release of corn could have the effect of holding the price down to about the level at which the release was made.

When farm products are pledged or mortgaged to secure price-support loans, or are acquired by CCC, it is vital that they be kept in safe storage until they can be moved into useful consumption. Government-owned and loan corn must be stored under the terms of a Uniform Grain Storage Agreement entered into between CCC and the operator of the storage facility, which may be a public facility or a facility owned by a farmer. In order to obtain a price-support loan, the farmer obtains a receipt for corn placed in storage, and uses this receipt as collateral for the loan.

At any time prior to the maturity date of the loan, the farmer may repay the loan and redeem the corn, or at maturity he may deliver it to CCC at a local facility if it is in farm storage. If the corn is in warehouse storage, and the farmer does not redeem it at maturity, CCC takes title to it.

A substantial part of the corn placed under price-support loans each year is held in storage on the farms where it is produced and remains there for at least the first year of the loan period. To encourage increased farm-storage capacity as directed by Congress, CCC has made recourse loans to farmers to finance new farm-storage facilities for grains and other storable crops. Such loans, which may not exceed 85 percent of the cost of the structures and facilities are payable in four annual installments, at an annual interest rate of 4 percent.

CCC has authorized reseal loan programs on certain commodities, primarily grains, for a number of years. Under these programs, farmers are permitted to continue their price support loans on commodities in storage on farms for additional periods and to receive storage payments. The storage payments appreciably increase farmers' income, and the grain is kept in position for consumption in producing areas.

SECTION 2. HARVESTING CONDITIONING AND STORAGE

By W. R. SCHNUG, Extension agricultural engineer, farm electrification
D. M. BYG, Extension agricultural engineer, farm machinery

The Harvesting System

Any method of harvesting corn for grain should provide the best overall balance of the following desirable characteristics

1. Adequate capacity to allow harvesting most of crop during favorable weather in the period between October 15 and November 15.
2. Low field losses.
3. Reasonable preservation of grain quality.
4. Most efficient use of available labor with consideration given to reasonable ease and convenience.
5. Reasonable equipment management demands on the operator for efficient harvesting operations.
6. Reasonable harvesting costs.

Unfavorable weather is one of the greatest problems in harvesting corn. Table 8 shows the effect of a heavy snow followed by rain on corn harvesting losses during the 1966 season.

TABLE 8—1966 Corn Harvesting Losses
(Bushels Per Acre)

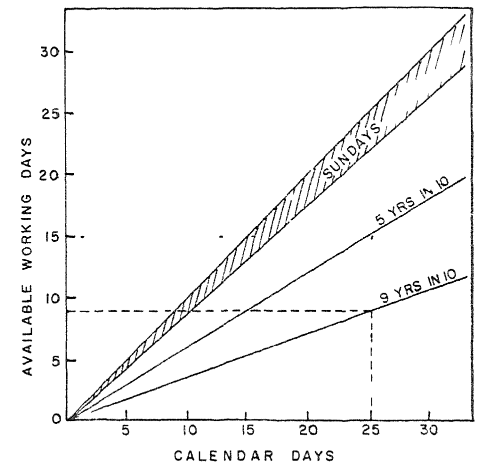
	Average Loss		Range of Losses	
	Picker	Combine	Picker	Combine
Before Nov. 2	4.0	6.8	1.0-9.0	3.4-16.4
After Nov. 2	8.1	11.9	0.7-13.0	4.1-22.3

Source: "Machine Losses in Harvesting Ear and Shelled Corn," D. M. Byg, W. E. Gill, J. E. Henry, and W. H. Johnson, Paper No. 66-611, American Society of Agricultural Engineers, December, 1966.

Weather risks can be reduced by planning to complete the haresting operation during the period October 15 to November 15 in which favorable harvesting weather is most probable.

A study of weather during this period reveals a direct correlation between days of 0.1 inch or more rainfall and days not suitable for corn harvesting.[5] This does not mean that 0.1 inch rainfall necessarily prevents harvesting, but it accounts for the influence of heavy rainfall followed by wet soil and crop conditions. Figure 4 represents an estimate of the probability of occurrence of days suitable for harvesting in central Ohio for the October 15 to November 15 period.

FIGURE 4—Available Working Days for Harvesting Corn in Central Ohio with less than 0.1 Inch Rainfall, October 15 - November 15 (5-day intervals)



Source: Barre, H. J., "Corn Harvesting and Handling," Mimeo Report, Dept. of Agricultural Engineering, The Ohio State University, 1964.

Suppose you plan to complete harvest 9 out of 10 years within 25 calendar days. Enter the graph of Figure 4 at 25 on the horizontal axis and move vertically to intersect the 9-years-in-10 line (as indicated by dotted line). Read on the vertical axis 8½ available working days (not including Sundays) to complete your harvesting operation. If you require 15 working days to complete harvesting, you can determine (at the intersection of lines drawn from 15 available working days and 25 calendar days) that there is only a 50 percent (or 5 years out of 10) probability of completing your harvesting in 25 calendar days.

Planning for corn harvest during a given period, such as October 15 to November 15, is greatly influenced by dates of planting, silking, and maturity of the crop. Agronomic research has discovered that all hybrid varieties mature 53 days after silking.[6] The varietal differences in maturity lengths of corn occur in the period from planting to silking and are greatly influenced by the heat energy available during that period. Early planting increases the probability of harvesting full-season hybrids during a favorable period.

The harvesting capacity required to complete the corn harvest in a given number of operating days can be estimated by reference to Table 9 and the example following the table.

[5] Newman, J. E., "The Weather Risk During the Corn Harvest," **Implement and Tractor,** 78: 21-22 (1963)

[6] Miles, S. R., "Maturity of Corn in Relation to Field Shelling," Proceedings of Conference on Field Shelling and Drying Corn, USDA, 1956

TABLE 9—Estimated Normal Harvesting Rate in Terms of Row Width and Ground Speed

Row Width Inches	Ground Speed in mph 1.5	2.0	2.5	3.0
	. . . . . . Acres per Row per Hour			
20	0.21	0.28	0.35	0.42
30	0.32	0.42	0.53	0.63
36	0.38	0.51	0.63	0.76
40	0.42	0.56	0.70	0.84

Example: If you have 200 acres of corn in 30-inch rows, allowing 20 full operating days for harvesting, the planned harvest rate should be 10 acres per day. Assuming an average speed of 2.5 mph, Table 9 indicates an average harvest rate of 0.53 acre per row per hour. If a 2-row machine is used, about 9½ hours of operation per day are required to produce the daily harvest of 10 acres.

The method illustrated in the example may be extended to predict the required machine size for any number of acres, number of harvesting days, and length of harvest day. Table 10 shows relationships between number of rows, width of row, and actual harvesting rates of combines operated by farmers under field conditions. An operator's ability to sense and respond to the efficiency of machine operation may affect the potential harvesting capacity, especially with larger machines.

TABLE 10—Rates of Harvesting Corn with Combines in Ohio Under Actual Field Conditions (1964-67)

Row Units	Speed mph	Width Inches	Acres per Hour
2-40's	2.6	80	1.5
3-30's	2.6	90	1.7
4-30's	2.2	120	1.9
4-40's	2.2	160	2.5
6-30's	2.0	180	2.5
6-40's	2.0	240	3.4
8-20's	1.6	160	1.8

Source: Byg, D. M., "A Study of Corn Harvesting in Ohio," 1964-67

Transfer of dry matter from stalk to ear is completed 53 days after silking, and at this time kernel moisture is commonly 35 to 40 percent. However, dry matter continues to be transferred from cob to kernel throughout the drying period.[6] In terms of harvested yield, the optimum harvest moisture for picking is 28 percent and for field shelling 24 percent.

Practically all the corn produced for grain in the United States is mechanically harvested by picking or field shelling. The following points of comparison of performance of these harvesting methods assume machines of current design operated under identical conditions of weather, crop, and operator skill:

Harvest Rate. Combines are available in a larger range of sizes than pickers, and much more shelled corn than ear corn can be hauled in a truck or wagon. Therefore, field shelling has at least a potential advantage in harvest rate.

Field Losses. Field shelling includes gathering, shelling, and cleaning the corn. The shelling operation usually occurs at a moisture content not favorable to clean, easy separation of kernel and cob. Therefore, field losses are predictably higher with field shelling than with picking. (Table 11)

TABLE 11—Machine Losses in Harvesting Corn by Pickers and Combine

(Bushels Per Acre)

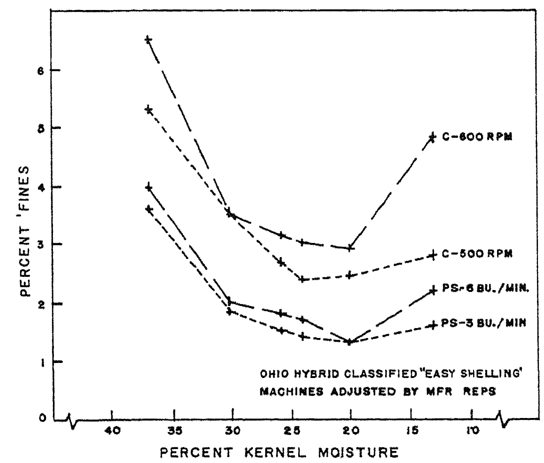
	Average Loss Picker	Combine [a]	Range of Losses Picker	Combine [a]
1964	4.8	6.4	0.3-14.0	2.3-29.4
1965	4.3	6.5	0.9-12.4	2.2-19.3
1966	5.4	9.3	0.7-13.0	3.4-22.3

[a] Combine losses allow for kernel tips remaining in cobs and for "fines" returned to ground. No account is made of damaged kernels and fines in grain tank. Plant population and estimated harvestable yield averaged slightly higher for combines.

Source: "Machine Losses in Harvesting Ear and Shelled Corn," D. M. Byg, et al, Paper No. 66-611, American Society of Agricultural Engineers, 1966

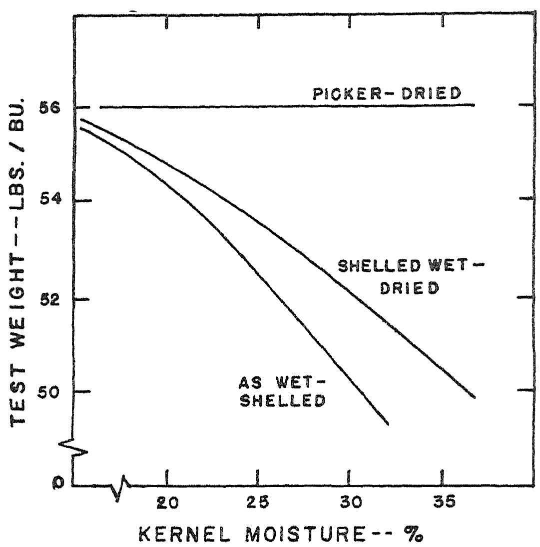
Grain Damage. The strength of attachment of kernel to cob is greater at higher moisture contents. Thus, field shelling produces much kernel damage ranging from invisible internal damage, tip loss, and slightly cracked kernels to completely pulverized corn. The combine may cause greater damage than the picker sheller at kernel moistures below 30 percenter. Figures 5 and 6 show the influence of corn moisture at harvest on kernel damage and test weight.

FIGURE 5—Corn Damage by Two Shelling Devices



Source: Adapted from Hall, Glenn E. and D. M. Byg, "Corn Losses and Kernel Damage When Field Shelling Corn," American Society of Agricultural Engineers, (1967)

FIGURE 6—Effect of Harvesting Treatment on Test Weight



Source: Johnson, Lamp, Henry, and Hall. "Corn Harvesting Performance at Various Dates," Transactions of ASAE, 6:268 (1963)

Adaptability to Weather and Crop Conditions. Self-propelled combines and picker-shellers have better traction on soft ground than pickers and picker-shellers with trailing wagons. Picking can begin at higher corn moisture, thus affording the opportunity of earlier harvesting in predictably more favorable weather.

Ease and Convenience. The granular form of clean shelled corn gives it an advantage over ear corn in handling ease and convenience. Shelled corn can be handled by more types of conveyors. The ease and convenience advantage of handling shelled corn is often overstated, however, by comparing a new, modern shelled-corn system with the antiquated ear-corn system it replaced. Ear-corn systems can be made easy and convenient to operate by proper planning and design.

Harvesting Cost. Table 12 shows the relationship between estimated machine costs and harvested volume for various sizes and types of machines.

Combination Method: A combination of the picking and field-shelling methods provides the following advantages for some farmers:

1. Corn and soybeans can be harvested on the same day without changing heads on the combine.
2. Picking can begin at higher moisture levels without incurring excessive grain damage, thus extending the harvest season into predictably more favorable weather.
3. Existing ear-corn handling and storage facilities can be used.
4. Potential value of cobs for feed or sale.

The principal disadvantage of the combination of methods is that equipment and facilities for both ear and shelled-corn systems must be maintained.

TABLE 12—Estimated Machine Costs of Harvesting Corn

Machine	Initial Cost	Thousands of Bushels 5	10	20	30	40	50
		Cents Per Bushel					
2-row, pull-type picker [a]	$2,500	12	8	5	4	3.5	—
2-row, mounted picker or picker-sheller [a]	3,500	13	9	6	5	4.5	—
2-row combine [b]	7,000	—	16	9	7	5	—
4-row combine [b]	11,200	—	—	13	9	7.5	6.5
8-row combine [b] (20-inch rows)	14,000	—	—	—	13	10.5	9.5

Note: Assumed Harvest Speeds: 2-row at 2.6 mph; 4-row at 2.2 mph; 8-row at 1.6 mph.

[a] Costs also include charge of $3/hr for tractor

[b] Based on 20 percent of initial combine cost as fixed cost with 70 percent assigned to corn harvesting, plus fuel and repairs as variable costs.

Corn Harvesting Machine Efficiency

Data of Table 13 indicate that excessive field losses can be avoided by knowing where and how losses occur, measuring these losses, and making corrective adjustments.[7]

TABLE 13—Component Harvest Losses

Loss Source	Median Losses [a] Picker	Combine	Top 20 Percent of Machines [b] Picker	Combine
Snapping Roll	2.0	0.6	1.1	0.4
Ear	1.0	2.2	0.2	0.5
Cylinder	—	.22	—	0.3
Separation	—	.18	—	0.2
Invisible	0.1	1.20	Nil	1.6
	3.1	4.4	1.3	3.0

[a] The median loss indicates there were just as many machines losing less than this amount as there were losing more.

[b] Less than 10 percent lodged; moisture range 20 to 30 percent, averaging 24 percent; average yield 105 Bu./A.

Source: Byg, D. M., "A Study of Corn Harvesting in Ohio," 1964-67.

Some useful tips for greater corn harvesting efficiency are:

1. Keep machines in good repair with all parts in place and functioning. Replace front snapping-roll bearings on pickers if they have more than 1/16 inch play.

[7] Information on procedures for measuring corn harvesting losses is available at each county office of the Cooperative Extension Service in Ohio or by writing D. M. Byg, Extension Agricultural Engineer, The Ohio State University, 2073 Neil Avenue, Columbus, Ohio 43210.

2. Run combine engine at proper "governed" speed and pickers at proper "P.T.O." speed.

3. Use a forward speed of 3 M.P.H.

4. Run snapping rolls closed tightly on pickers. Adjust control linkage if necessary.

5. Close stripper plates or snapping bars only enough to prevent ears from passing through.

6. Chain flights over stripper plates should extend beyond edge of plates by ¼ inch.

7. Ears should be snapped **near upper third of snapping roll.** On combines, this is regulated by the aggressiveness of the snapping rolls; on pickers, by forward speed.

8. Drive accurately on paired rows spaced to match your harvesting machine.

9. Gathering snouts should float on the ground and gathering chains should be just above the ground. (Be alert for stones.)

10. Start harvesting early — about 30 percent moisture for pickers and 28 percent moisture for combines.

11. Study operator's manual and make basic settings as specified for cylinder and shoe adjustment.

12. Measure losses and make corrective machine adjustments whenever crop conditions change.

13. Strive to match field capacity of harvesting equipment to acres of corn produced and rain-free days available for harvesting.

14. Select hybrid corn varieties that will stand up under your farming conditions, and will dry to desirable harvest moisture by early October.

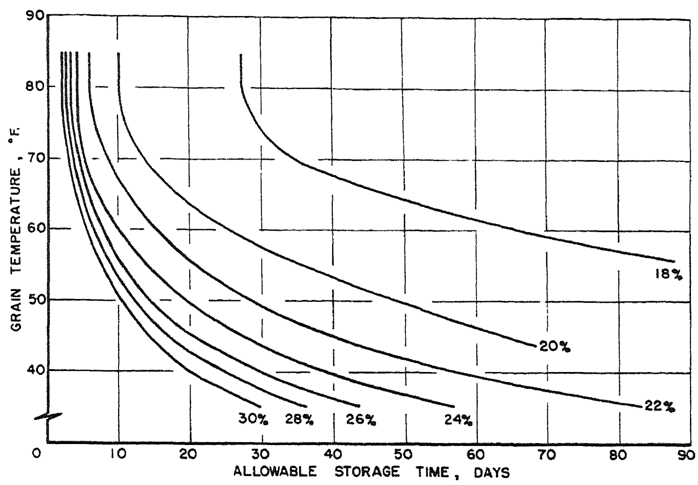
Conditioning and Storage

Conditioning and Storage Requirements

Harvested corn is a perishable product. The processes of respiration and fermentation and the action of micro-organisms, insects, and rodents reduce the quality and value of corn for seed, for feed, and for the milling processes. The degree of damage depends on the supply of oxygen and moisture, and prevailing temperatures. Kernel damage greatly increases the rate at which the destructive processes occur.

The risk of loss in handling and storing corn can be greatly reduced by conditioning the corn and its environment to limit available oxygen, moisture, and temperature. Drying and aeration of corn controls both moisture and temperature and thus is more dependable for preserving corn quality and value than any conditioning operation that controls only one factor. Figure 7 shows the relationship between corn moisture, temperature, and allowable "safe" holding time.

FIGURE 7—Allowable Time for Holding Shelled Corn with No Significant Growth and No More than ½% Dry Matter Loss.



Source: USDA, Grain Storage Research Laboratory, Ames, Iowa.

The conditioning and handling operations for a particular system are determined by the form and condition of the harvested crop and the probable disposition of the crop. It seems reasonable to assume that the benefits of harvesting corn at higher kernel moistures are sufficient to assure that much, if not most, of the crop will be harvested at moisture contents of about 25 percent. Current harvesting trends indicate that most of the crop will be field-shelled, resulting always in a product which is damaged to some degree. Corn harvested on any given farm may have some immature kernels, rotting cobs, and moldy kernels. Each of these factors may increase risk of lowered value, and places greater demand on the system for conditioning, handling, and storing corn.

There is no practical "risk-free" method of preserving corn quality after harvest. Three methods — drying and aeration, oxygen-free storage, and low temperature holding — are discussed in this publication. Each method represents a compromise between "reasonable risk" and "justifiable expense" in relation to the value of the corn. In many cases, a combination of two or more of these methods may be most satisfactory.

The Corn-Drying Process

In the drying of corn, heat energy is transferred from the air to the grain. Some of this energy is absorbed by the moisture in the grain. Some of the moisture then vaporizes and moves from the grain to the air. The higher the air temperature, the greater the rate of heat and moisture transfer. Thus, the rate of moisture loss from the grain declines as grain moisture content declines. A condition is finally reached in the drying operation at which the pressure exerted by the grain moisture is equal to the pressure exerted by the water vapor in the air. This condition is called "hygroscopic equilibrium" and is the condition at which no further drying of the grain is possible. Table 14 lists moisture contents for shelled corn at which the corn is in equilibrium with air of given temperature and relative humidity.

TABLE 14—Equilibrium Moisture Contents of Corn Relative to Air Temperature and Relative Humidity

Air Temperature	Relative Humidity					
	40	50	60	70	80	90
30°	11.3	13.1	14.6	16.4	18.7	22.5
40°	11.0	12.5	14.0	15.5	17.8	21.5
50°	10.6	12.0	13.3	14.8	16.9	20.5
60°	10.2	11.6	12.7	14.2	16.0	19.5
70°	9.7	11.1	12.0	13.5	15.4	18.5
80°	9.1	10.5	11.2	13.0	14.8	17.4

Source: Adapted from Krewatch, A. V., "Corn Harvesting, Drying and Storage," Maryland Extension Bulletin 195, 1962

There is a definite time period within which corn of a given moisture content and temperature must start to dry if mold growth and excessive dry matter loss are to be prevented. (See Figure 7.) There is also a minimum rate of moisture removal which should be equalled or exceeded during the drying period. An increase in drying rate above the minimum rate required does not necessarily improve corn quality. Drying in storage requires relatively low drying rates. In systems in which corn is dried and transferred to storage, much greater drying rates are required. The drying rate produced by a system is determined by initial corn moisture, air-flow rate, air temperature, and relative humidity.

The air-flow rate of a drying system is measured as cubic feet per minute (cfm) per bushel of grain volume. Minimum air flow rates are commonly associated with in-storage drying systems for both ear and shelled corn. A common recommendation of minimum air-flow rate for drying ear corn of 30 percent moisture is 5 cfm per bushel. Increasing the air-flow rate increases drying rate, but the increase in drying rate per additional horsepower required declines. Therefore, greatest drying efficiency is obtained at minimum air flow rates. Larger air-flow rates are required with higher drying-air temperatures. For every combination of grain-layer thickness and air temperature, there is a corresponding optimum air-flow rate.

The amount of air that a fan-motor unit will force through corn is determined by the thickness and density of the grain layer. Damaged corn, husks, stalks, silks, and other debris increase the grain density and create greater resistance to air flow. The fan-motor unit must develop sufficient static pressure in the plenum, or supply chamber, of the system to overcome resistance of the grain. The greater the static pressure, the less air delivered per horsepower. Fan performance charts usually list air delivery in cfm for several levels of static pressure expressed as "inches of water."

Drying systems are sometimes classified by the temperature of the drying air. Natural (unheated) air systems are common to ear-corn drying and are sometimes used for small quantities of shelled corn. Supplemental heat systems commonly add enough heat to raise air temperature 15° to 20° F. or may add heat on a signal from a humidistat control to maintain a pre-determined relative humidity of the drying air. Such systems are common to in-storage drying of both ear and shelled corn. High-temperature systems include all systems using constant drying-air temperatures greater than 100° F., although the designation is most often used for systems with air temperatures in the range of 150° to 240° F.

Heating the drying air increases drying rate by increasing the rate of heat transfer to the grain and by increasing the moisture-holding capacity of the air. However, the quality of corn dried at high air temperatures may be damaged. Most authorities agree that kernel temperatures should not exceed 140° F.[9] Kernel temperature is a function of kernel moisture, air-flow rate, air temperature, and length of exposure to the heated air. Higher-moisture corn can be exposed to much higher air temperature because more of the heat is absorbed by vaporized moisture and is thus unavailable to cause excessive kernel heating. The accumulation of heat in the kernel is determined by air temperature and time of exposure. Excessive kernel temperatures may be produced by relatively short exposure to air at 240° F. or by longer exposure to air at 150° F. Large air-flow rates minimize kernel overheating with high air temperatures. Commonly recommended air temperature limits related to probable uses of corn are:

Seed . ...110°F.
Milling .... 140°F.
Livestock feed ....180° - 200°F.

Drying efficiency of any process or system is usually defined as the ratio of useful work or energy output to total energy input. The only useful work performed by a corn-drying system is the removal of water from the grain. The input to the system

[8] The terms "kernel moisture," "corn moisture," and "moisture content" as used in this discussion mean the ratio of water weight to total weight of a corn sample. Further information is available in Ohio Extension Bulletin 425, "How to Determine Shrinkage in Grain."

[9] Kernel temperature refers to the equilibrium temperature of the kernel and the surrounding air.

includes the energy equivalent of fan power, added heat, and any other energy input required to operate the system. On this basis, those drying systems which operate near the minimum drying rate are usually most efficient.

Probably the most significant performance rating of a drying system is drying capacity, or the ability of the system to dry a specific volume of corn per hour or day over a specific range of corn moisture contents. Such ratings are usually given in terms of bushels per hour (or day) for specified initial and final moistures. The drying capacity of a system should be large enough to permit intake of corn at the average daily harvest rate and should be determined on the basis of drying corn of initial moisture content no less than 25 percent.

Ear-Corn Storage, Drying, and Handling

A bushel of clean ear corn at 15.5 percent moisture weighs 70 pounds and requires about 2½ cubic feet of storage volume. Assuming an average shell-out of 80 percent, this volume of ear corn yields 56 pounds of kernels and 14 pounds of cobs. Earn corn, as commonly harvested, requires 3½ to 4 cubic feet of storage volume per bushel, depending on moisture content and amount of husks, silks, and other debris.

Ear corn may be stored in a great variety of structures ranging from "temporary" plastic-covered piles and snow-fence cribs to large-volume storages with mechanical drying and highly mechanized handling systems. Regardless of the size, shape, and construction details, every ear-corn storage should provide the following basic requirements:

1. Storage should be located on a well-drained site with an all-weather driveway and traffic area for haul vehicles. Elevation of floor above grade prevents surface water from entering the storage. Vapor barrier between floor and fill prevents entrance of ground moisture.
2. Storage should provide reasonable protection of corn from weather; particularly, against rain and snow falling on top of corn.
3. Storage should be structurally sound to withstand lateral pressures exerted by corn. Storage design should provide maximum unobstructed space.
4. Storage should be rodent-proof.
5. Storage should be designed and constructed so that corn of 25 percent or greater moisture can be safely stored and dried. Storage design may provide for either natural or mechanical ventilation.
6. Storage should provide for reasonable ease and convenience in loading and unloading. Mechanized handling features, including planned flow of haul vehicles to and from storage, should be included in basic storage design rather than added as an afterthought.

Ear corn may be harvested and stored successfully at kernel moistures up to 25 percent in naturally ventilated cribs if the free-air-to-free-air distance through the corn is limited to 6 to 8 feet. Horizontal or vertical flues allow for either increasing the crib width or storing corn of higher moisture levels. Cross-flues for rectangular cribs should have a minimum cross-section area of 2 square feet while vertical cylindrical flues should have a minimum diameter of 18 inches. If corn of as much as 30 percent moisture is stored in a naturally ventilated crib, no ears should be more than 2 feet from a flue or side of crib.[10]

Naturally ventilated storage facilities should be located and aligned so as to provide maximum surface exposure to prevailing winds. Single rectangular cribs should, therefore, be aligned in a NW-SE or N-S direction. Double-driveway cribs and A-frame cribs are best aligned in an E-W direction. Structures should be located so that they are not shielded by buildings or other wind breaks.

A properly designed and installed mechanical drying system[11] permits harvest and storage of ear corn at kernel moistures up to 35 percent. Mechanical drying also provides advantages in that storage width need not be limited by ventilation consideration, and more economical structural dimensions may be used. Mechanical drying may be adapted to storages of almost every size and shape. The trend in modern ear-corn storage design is toward wider "clear-span" structures. The length and width dimensions of such structures are usually much greater than the storage depth, thus suggesting the term "flat storage."

Most earn-corn drying systems are relatively simple of design, construction, and operation. The standard minimum air-flow recommendation for drying 30 percent moisture corn is 5 cubic feet per minute (cfm) per bushel. Greater air-flow rates produce more rapid drying, but the increase in drying capacity per additional horsepower required decreases with increasing air flow. A fan and motor unit capable of supplying the required air flow at a static pressure of 1½ to 2 inches should be used.[12] Propellor fans are most commonly used in ear corn drying.

10 These recommendations developed by R. C. Miller, professor emeritus, Department of Agricultural Engineering, The Ohio State University, who pioneered in the development of corn drying systems in Ohio.

11 Principal source of information on mechanical drying systems is USDA. Miscellaneous Publication 919, "Mechanical Ventilation of Ear Corn," 1965.

12 Static pressure is the air pressure that must be developed to move the required amount of air against the resistance afforded by the structure and the grain. In grain drying, this pressure is commonly measured with a liquid manometer and expressed as inches of water or inches-water gage (wg). Fan performance tables usually cite air delivery (cfm) for various static pressures in inches of water.

Weather conditions throughout the Corn Belt during the fall harvest season are generally favorable to natural air drying. Recent experience has shown, however, that the use of supplemental heat is quite advantageous in assuring continued drying during periods of low air temperatures and high relative humidities. Supplemental heating is designed to provide an air-temperature rise of 15° to 20° F.

High-temperature drying infers an air temperature rise greater than 15° to 20° F. which may be needed for faster drying where more than one crib of corn must be dried with portable drying equipment. Air temperatures greater than 100° F. are rarely justified. The maximum air temperature should be limited to 135° F. to prevent kernel damage. Ear-corn drying is essentially an in-storage drying operation in which corn dries in a pattern proceeding outward from the air source. Thus, overdrying of some of the corn must be expected with heated-air drying.

The volume and shape of the storage dictate the arrangement of the air distribution system for ear-corn drying. Center-duct systems are commonly used in storages of widths up to 25 feet. For greater storage widths, two large ducts or a center duct and a lateral arrangement may be used. To limit static pressure requirements, the air-flow distance through corn in any direction is usually limited to 15 feet. Duct air velocities less than 1000 feet per minute are desirable. Therefore, the general recommendation for duct size is 1 square foot of clear cross-section area per 100 cfm of air-flow. The dimensions of the duct to produce the required cross section is dictated basically by the storage dimensions.

A minimum of 3 to 5 square feet of clear exhaust opening should be provided per 100 cfm of air flow. This is a particularly important consideration in design of drying systems for tight-sided storages.

In operating the drying system, the fan is started as soon as the duct is covered with 2 feet or more of corn. Cut-off panels in the main duct can be used to restrict air flow to filled sections of the storage before moving the elevator or distributor. Screening the corn during filling removes much shelled corn and dirt which may impede air flow and restrict drying. With unheated-air systems, the fan is operated continuously when air temperatures exceed 50° F. until the corn most remote from the air supply is dried to 18 to 20 percent moisture. If the weather is favorable, the drying period for 30 percent moisture corn is usually 15 to 20 days. If unfavorable weather prevails, the drying period may be prolonged to 4 to 6 weeks. During periods of cool and humid weather, the fan may be operated only a few hours each day to keep the corn cool until the return of more favorable drying weather.

Supplemental heating may reduce the drying period to 7 to 10 days in favorable weather. Drying with a constant higher air temperature usually allows completion of drying within a week regardless of weather. It is important that the corn be cooled to the surrounding temperature after heat is discontinued.

After the corn is dried, it can be safely held in storage until late spring by operating the fan occasionally to cool the corn and remove migrant moisture. The frequency and duration of such aeration periods depend on the prevailing weather. For average Ohio winter weather conditions, a few hours aeration every 10 days to 2 weeks is sufficient. The corn should also be aerated when 3-to 5-day periods of increasing or decreasing mean daily temperatures are observed. This rule applies to cooling corn in the fall and warming corn in the spring. The simplest check of aeration is to check the temperature of the supply air and exhaust air. If there is no measurable difference in these temperatures, aeration may be discontinued.

With unheated air systems, the corn dried to 18 to 20 percent in the fall may be dried to low moisture levels when daytime air temperatures increase above 70° F. in the spring. Such additional drying is necessary for penalty-free sale or for holding corn in storage during summer months.

Tables 15 and 16 show typical storage costs and drying costs for ear corn.

TABLE 15—Typical Ear-Corn Storage Costs Per Bushel

	Average Initial Cost	Annual Charge
Round Steel Crib	$0.43	$0.04
Single Crib	0.60	0.06
A-Frame Crib	0.70	0.07
Double-Crib, overhead bins	1.00	0.10

Source: Barre, H. J., "Points to Consider in Selecting a System for Harvesting and Handling Corn," Mimeo, Department of Agricultural Engineering, The Ohio State University, 1966.

TABLE 16—Ear-Corn Drying Costs
(Cents per Bushel

Initial Moisture Level	Dry to 18 Percent		Dry to 15.5 Percent	
	Unheated Air [a]	Heated Air [b]	Unheated Air	Heated Air
30	5.5	14.2	6.0	15.7
28	5.0	12.9	5.5	14.4
26	4.5	11.7	6.0	13.2
24	3.6	9.2	4.1	10.7

[a] Investment of $1200, fixed cost 2.7c per bu. on base of 4000 bu.

[b] Investment of $2000, fixed cost 6.0c per bu. on base of 4000 bu. Indirect oil-fired heater.

Source: Purdue University Station Bulletin 630, "An Economic Analysis of Drying Wheat and Corn on Indiana Farms," July, 1955.

Ear corn varies greatly in density, in volume, and in handling characteristics. Clean ear corn has an "angle of repose" of about 35°. However, due to the "bridging" characteristics of ear corn, continuous gravity flow is seldom achieved at pile slopes less than 60°.

Portable flight conveyors are most commonly used to elevate ear corn into storage. In centralized storage, the vertical bucket or cup conveyor (commonly known as the "permanent leg") is a very efficient and versatile method of elevating ear corn. Drag conveyors are commonly used to remove ear corn from storage. Single-and double-chain flight and expanded-metal mats perform satisfactorily as drag conveyors. Typical ear-corn handling costs are 2 cents per bushel to haul from field and unload and 2.5 cents per bushel to shell from storage.[13]

Shelled-Corn Drying, Handling, and Storage

The major differences between drying shelled corn and drying ear corn are:

1. Kernel damage makes much faster drying necessary for shelled corn.
2. The granular nature of shelled corn allows the use of flow-type drying and handling systems considered impractical for ear corn.
3. Less moisture is removed per bushel of shelled corn dried because there is no cob.
4. Shelled-corn drying systems are usually sold as "package" systems as opposed to the custom design system common to ear-corn drying.

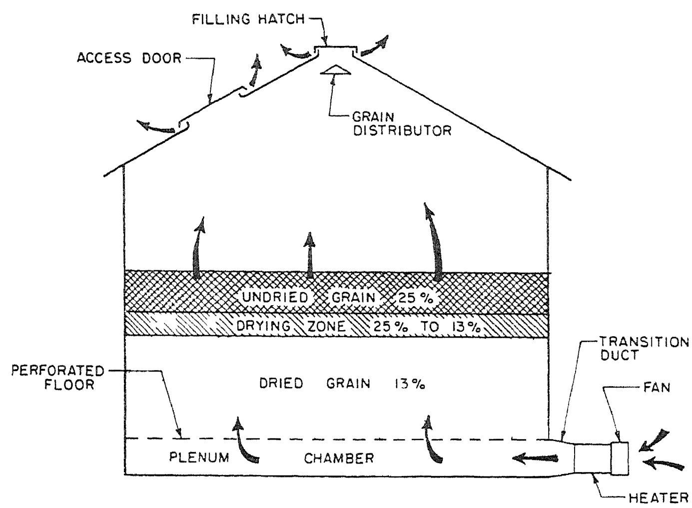
Aside from these differences, the basic principles of grain drying apply equally well to drying shelled corn as to drying ear corn.

Shelled-corn drying systems are commonly classified by type as follows: in-storage, bin-batch, column-type batch, and continuous-flow. Innovations such as stirring devices and recirculators for bin drying systems tend to obscure some of the differentiation by operating characteristics between these systems. However, the basic features of the systems differ sufficiently to merit such classification.

In-storage (layer) drying is the drying of multiple layers of wet corn in the storage structure. An average air flow rate of 5 cfm per bushel is common for in-storage systems. Natural air may be used in drying smaller volumes (2000-3000 bushels) of corn with moisture content no greater than 20 percent. Most in-storage drying systems provide supplemental heat sufficient to produce either a constant air-temperature rise of 15° to 20° F. or an air relative humidity of 55 to 70 percent, depending on outdoor air temperature.

[13] Barre, H. J., "Points to Consider in Selecting a System for Harvesting and Handling Corn," Mimeo, Department of Agricultural Engineering, The Ohio State University, 1956.

FIGURE 8—Typical Drying Zone Pattern of In-Storage Drying



Source: Circular 916, Cooperative Extension Service, University of Illinois.

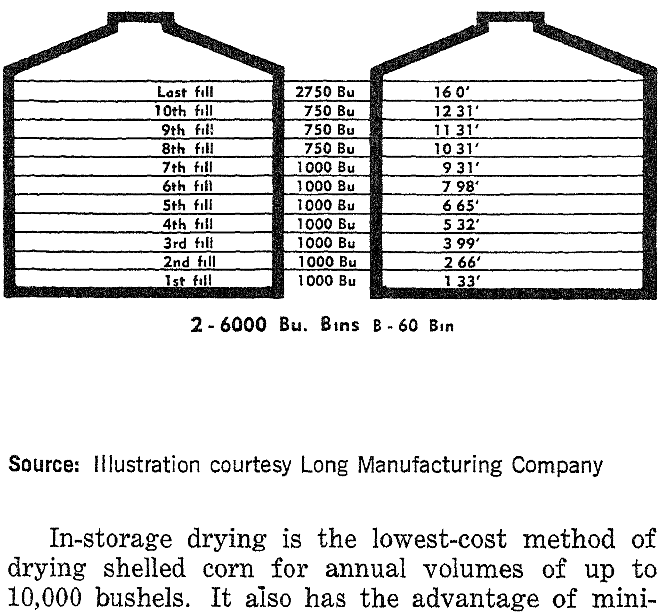
The drying pattern for in-storage drying is illustrated in Figure 8. Drying begins in the layer of corn at floor level and proceeds upward in a frontal pattern. The drying air is quickly saturated as it moves upward through the corn. No drying occurs above the level at which the air is saturated. As the corn nearest the floor becomes drier, it gives up less moisture to the air and the saturation point, or "drying front," moves upward in the wet corn.

After about 24 hours of such operation, three distinct zones appear in the corn. The lowest zone is that of corn dried to near the final desired moisture. Above this dried zone is the drying zone in which corn moisture condition ranges from nearly dry at the bottom to that just starting to dry at the drying front. Above the drying front is the zone of corn at the intial moisture level. The rate at which the drying front moves upward through the corn is determined by the initial corn moisture, air-flow rate, air temperature, and relative humidity. For example: if the air flow rate is 5 cfm per bushel, air temperature is 70° F, and the relative humidity is 55 percent, the drying front will move about 2 feet in 24 hours through 25 percent moisture corn. During this period, only about 10 inches of corn nearest the floor would be dried to, or near, the final equilibrium moisture.

The principle of equilibrium moisture content is a critical factor of in-storage drying. Table 14 shows that corn of 11.5 percent moisture is in equilibrium with air at a temperature of 70° F. and a relative humidity of 55 percent. If the humidistat control setting is increased to 70 percent, the corn will dry to a final moisture of 13.5 percent, eliminating 2 points of overdrying, but the rate of drying will be decreased. Table 14 suggests humidistat settings for several ranges of outdoor air temperature which represent a compromise between limited overdrying and an acceptable drying rate.

There are several satisfactory methods of determining the rate at which wet corn can be added to the system. Some manufacturers and many Ohio operators prefer the "daily fill" method which permits the operator to add a given depth of wet corn each day. Figure 9 represents a typical manufacturer's recommendation for daily fill, using two bins with one fan and heater unit. Each manufacturer develops a fill schedule and management program best suited for his particular system. These recommendations should be observed in operating the system until such time as the operator gains experience with the system and can design ways to adjust system operation to meet changes in his harvesting and handling operations.

FIGURE 9—Typical Recommendation for Daily Fills of 25 Percent Moisture Corn in Two 24-Foot Diameter Bins



Source: Illustration courtesy Long Manufacturing Company

In-storage drying is the lowest-cost method of drying shelled corn for annual volumes of up to 10,000 bushels. It also has the advantage of minimum handling requirement from harvesting to storage. The major disadvantages of the system are a relatively slow drying rate and greater management requirement to avoid spoilage due to drying too slowly and excessive overdrying. Because of low air-flow rates, in-storage drying is not well adapted to use in the very cold weather often encountered in late November and December.

Batch-in-bin drying is a very popular method of drying shelled corn in Ohio for annual drying volumes ranging from 10,000 to more than 70,000 bushels. The batch size usually represents the bushels harvested daily, and the bin size is selected to accommodate this volume with a batch depth of 2½ to 3 feet. For example: if the daily harvest rate is 2,000 bushels, a bin providing capacity of about 700 bushels per foot of depth is selected. A bin with a diameter of 36 feet is a good choice for this system.

Air-flow rates of 15 to 60 cfm per bushel are used in bin-batch drying. The current trend is toward the use of multiple-fan and heater units with constant drying-air temperatures of 120° to 130° F. As soon as 1 foot of wet corn is placed in the bin, drying begins. A common schedule is 16 to 18 hours of drying and 2 to 3 hours to cool and unload. The drying pattern is similar to that of in-storage drying so that at the end of the drying period there is commonly a difference of 5 to 8 moisture points between top and bottom corn. Thus, the operator must learn by experience with his system the moisture level of the top corn at which to stop drying so as to produce the desired "blend" moisture in unloading. Manufacturer's literature usually gives estimates of drying time for given batch depths and corn moistures.

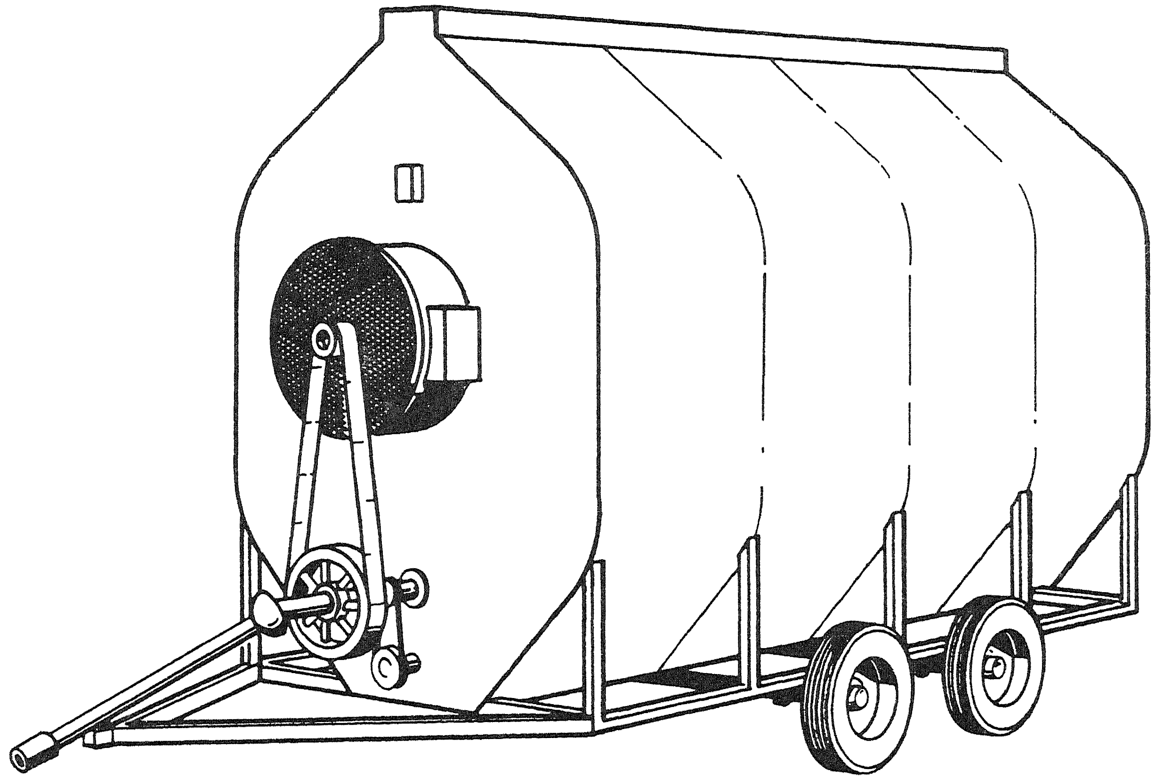
The major advantage of bin-batch drying is large drying volume capability at moderate investment in drying and handling equipment. Labor requirements in loading and unloading are less than with nonautomated, column-type batch drying systems. Most bin-batch systems provide storage potential by changing the mode of operation to that of layer drying for drying the last of the crop in storage. The major disadvantage of bin-batch drying is the management requirement for most efficient operation.

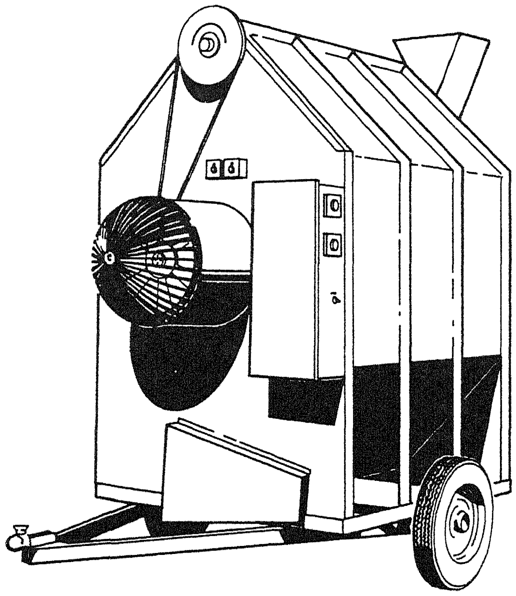
The term "batch dryer" usually refers to a system in which the corn is dried in vertical columns ranging in thickness from 12 to 24 inches. Batch sizes range from 40 to 600 bushels with a variety of shapes, or configurations, as illustrated in Figure 10.

Air-flow rates for batch drying range from 40 to more than 100 cfm per bushel with air temperatures of 150° to 250° F. Average heating-cycle time for conventional batch dryers in removing 10 percentage points of moisture is 2 hours, with an additional 30 to 45 minutes for cooling the corn. Most batch dryers having a grain-column thickness greater than 12 inches offer recirculation either as a standard or optional feature.

The trend in modern batch-dryer design is toward automation of the complete drying cycle, including loading and unloading. Rapid cycling of the system permits more batches to be dried per day, thus greatly increasing the drying capacity. Time-cycle control of system operation reduces the demand for both labor and supervision. Management is still required, however, to check initial and final corn moistures and to correct control settings when necessary. A disadvantage to automation of batch-dryer operation is the need for wet-corn holding capacity ahead of the dryer and increased investment in more sophisticated handling equipment and controls.

Continuous-flow drying systems are high-temperature, high-air flow, high-capacity systems best





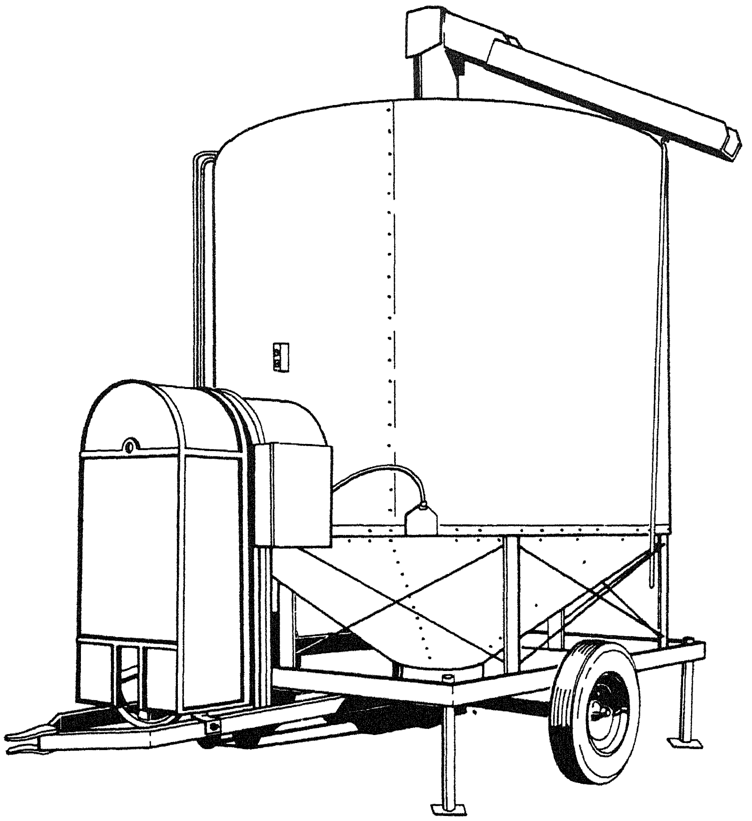


FIGURE 10—Typical Batch Dryers

Source: AE-67, "Selecting A Grain Drying Method," Cooperative Extension Service, Purdue University.

adapted to corn harvesting, handling and storage systems of annual volumes of 20,000 bushels or greater. Air-flow rates of 100 cfm per bushel or greater and air temperatures of 180° to 240° F. are typical of continuous-flow dryers. The name of these systems is derived from the fact that both air flow and grain flow are continuous during the drying operation. Continuous-flow dryers are of either horizontal-column or tower type, as illustrated in Figure 11. The upper portion of the plenum and grain columns is the drying section and the lower portion is the cooling section. The rate at which grain moves downward in the dryer is determined by an exhaust air thermostat control which regulates the speed of metering rolls, or sweeps, at the bottom of the cooling section. Some models provide for turning the corn during drying either by the shape of the drying column or by baffles inserted in the column. Power requirements for continuous-flow dryers range from 20 to 100 horsepower.

A major advantage of continuous-flow drying is the fact that tests of final grain moisture may be taken at any time and adjustments may be made to gain greater drying accuracy. These systems can be easily adapted to automatic control which reduces labor and management demands. These benefits, however, are possible only with completely integrated handling and control systems. Because of greater investment costs, continuous-flow is economically practical only with large-volume operations.

Fuel and Power

Natural gas is the most economical and most convenient source of heat for corn drying in those areas where it is readily available at the pressures required. However, the limited availability of natural gas in most farm areas of Ohio has made liquified petroleum (LP) gas the fuel for most drying operations. LP gas (propane) is usually available in adequate supply during the drying season in most areas of Ohio. Price of LP gas has shown both area and seasonal fluctuation depending on supply and dealer competition. It is wise to negotiate for your gas service well in advance of the drying season.

One major problem of fuel supply is failure of liquid LP gas to vaporize fast enough in cold weather to supply large vapor-burning heaters. Rapid absorption of heat by the liquid fuel can cause icing of valves and regulators. This problem is minimized by either connecting two large supply tanks in parallel or by the use of auxiliary vaporizers. **SAFETY NOTE.** MAKE CERTAIN THAT TANKS, VALVES, REGULATORS, LINES, AND FITTINGS ARE PROPERLY INSTALLED AND ADEQUATELY SHIELDED FROM HEAT AND PHYSICAL DAMAGE. Propane expands tremendously in changing from the liquid phase to the vapor phase. Thus, a small leak can create a serious fire hazard in a very large area.

At the present time, fuel oil is not popular in the drying of shelled corn because of commercially objectionable odors left in the corn when oil is direct fired. New developments in oil burners coupled with the existing cost per unit heat advantage of oil over LP gas may increase the popularity of oil as a dryer fuel in the future.

Electrical power has very significant advantages of cost, operational convenience, and reliability over tractor PTO power for drying operations. However, the cost advantage of 1/2 to 3/4 cent per bushel depends on the use of electricity at the generally prevalent low farm rates for single-phase service. The electrical demands of many drying systems are greater than can be readily accommodated within the single-phase service policies of many electric suppliers. Three-phase power is generally too costly for seasonal, peaking loads such as corn drying. Phase conversion is a possible solution for some of these problems, and some systems will permit use of larger single-phase motors. In any case, the electric supplier should be consulted early in the design phase of a corn-drying system.

Dryeration

One of the major problems of high-temperature drying of shelled corn is that of stress cracks formed by the contraction of a dry, brittle hull over a warm, relatively-moist kernel interior. The problem is one of too rapid cooling coupled with unequal moisture distribution in the kernel. The "dryeration" process was developed by USDA researchers at Purdue University to improve corn quality by reduction of stress cracking.

Figure 12 is a schematic representation of the dryeration process. Hot corn is removed from the dryer at 1½ to 2 moisture points greater than the desired final moisture and transferred to the dryeration bin. The hot corn is allowed to "steep in its own juice" for a period of 4 or more hours. This allows the moisture in the kernel to migrate outward and soften the hull. The corn is slowly cooled by an average air flow of 1/2 cfm per bushel and then transferred to storage. In addition to improved corn quality, the dryeration process affords the opportunity to increase the drying capacity of a given system by 40 to 60 percent[14] Additional investment and an additional handling operation to manage are the principal disadvantages of the dryeration process.

Stirring

Stirring of corn with an open, vertical screw has become a very popular practice with bin drying systems. The major advantages offered by stirring are increased drying rate, blending of grain, and elimination of the top-to-bottom moisture difference common to bin drying systems. Stirring is most advantageous for bin-batch systems in that much greater depths of corn may be dried, thereby permitting extension of the batch-drying period over

[14] For detailed information on design, installation, and operation of dyeration facilities, see Purdue University Publication AE-72, Dryeration, Better Corn Quality With High Speed Drying."

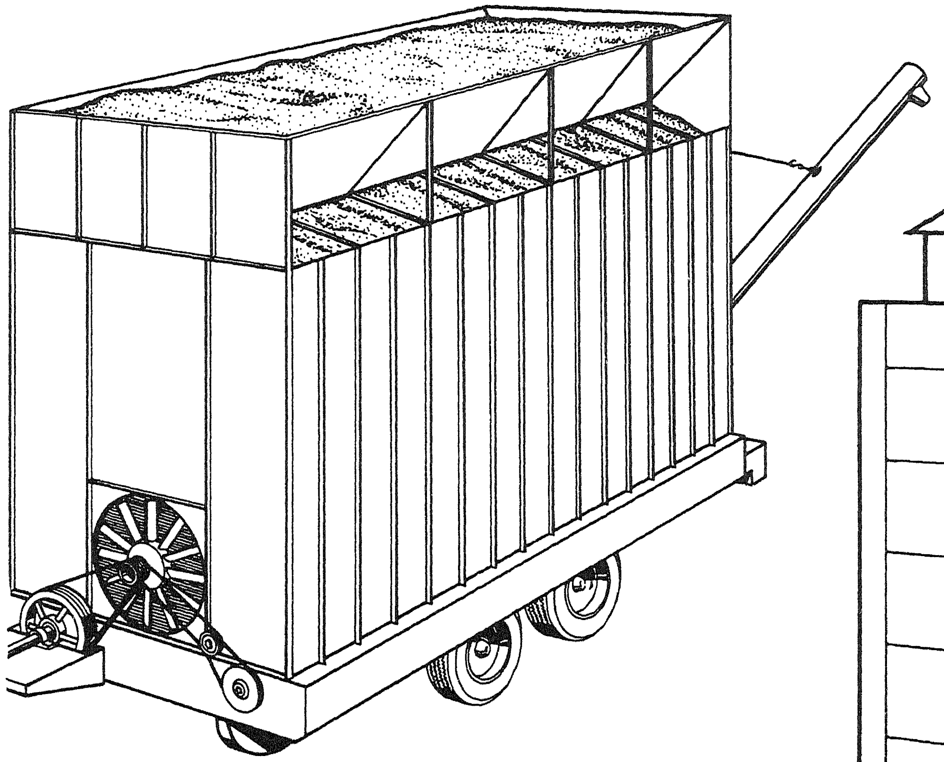
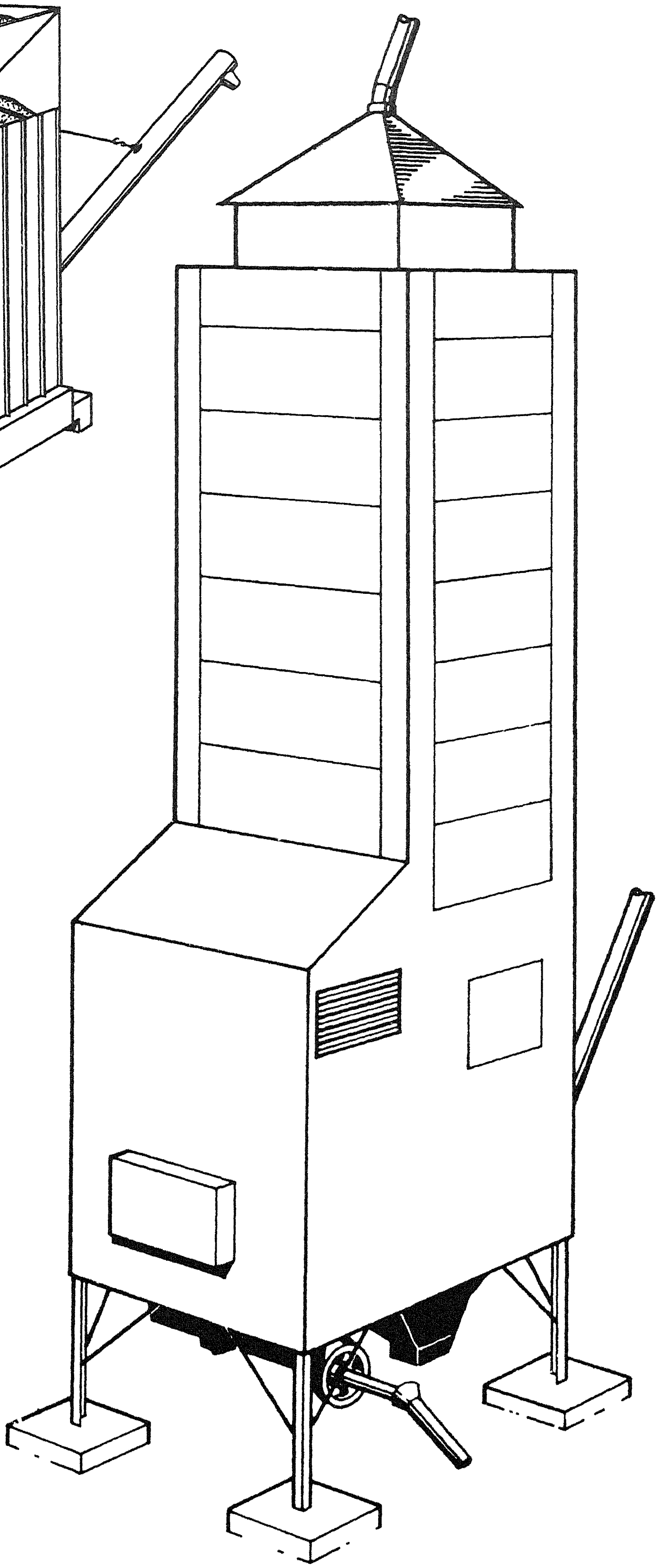
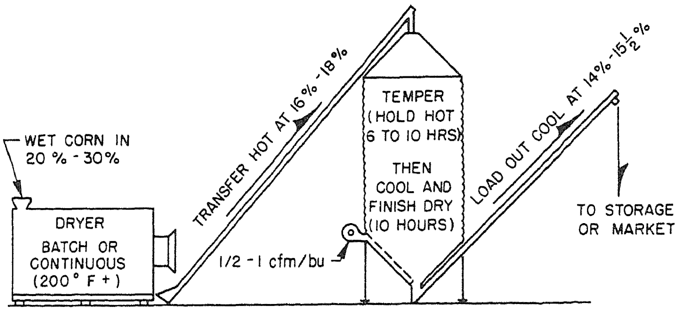


FIGURE 11—Typical Continuous-Flow Dryers



Source: AE-67, "Selecting A Grain Drying Method," Cooperative Extension Service, Purdue University.

FIGURE 12—Schematic Flow Diagram of the Dryeration Process



Source: Extension Bulletin AE-72, "Dryeration," Purdue University.

two or more days with less frequent unloading. The major disadvantages of the practice have been equipment failure and additional investment for in-storage systems of fixed annual capacity.

Equipment of two basic designs is available, and these differ in the method of support and movement of the vertical-screw drive unit and in the stirring pattern. Both single and multiple screw units are available in each type. Although some differences in functional and mechanical performance between the two systems have been observed, these differences are not nearly as significant as the potential benefits afforded by stirring and the problems which have been met in managing the stirring operation.

Cleaning

The problems created by damaged kernels, particularly meal and other fine material, both in drying and storage are so serious as to make cleaning the corn a necessity. Dry corn is more easily and thoroughly cleaned by screening than wet corn, and screening the dry corn greatly reduces the possibility of spoilage due to concentrations of fine materials in storage. Dry screening also removes excessive foreign matter that might result in price discount if the corn is sold after drying. Therefore, if only one cleaning operation can be fitted into a drying and handling operation, the cleaning should be done after drying.

Batch and continuous-flow drying operations may be seriously affected by fine materials which produce uneven drying and reduced drying capacity. In such cases, screening the wet corn may also be justified for efficient operation. A simply-constructed cleaning device consists of a wood frame 2 feet wide, 8 to 10 feet long covered with either 12/64-inch grain screen or ¼-inch hardware cloth with a 40 to 45-degree slope of the screen surface. Many commercial rotating cleaners are also available.

Low Temperature Holding of High-Moisture Corn

Rapid harvesting of high-moisture shelled corn often creates a need for a low-cost method of providing short-time holding capacity. For the cash-grain producer, such capacity may allow continued harvest while local elevators are overloaded with wet corn. This method may also serve as a low-cost "surge-pile" alternative to increasing drying capacity to match increased harvest rates.

A low-cost method of holding wet corn between plastic sheets was developed recently at the University of Illinois.[15] One or more large sheets of 4 mil or 6 mil polyethylene film is placed on the ground, and the wet corn is piled on the plastic. The top plastic sheet is placed on the pile and the edges of top and bottom sheets are folded together and tucked under the pile. The approximate capacities of rectangular piles of clean shelled corn is shown in Table 17.

A suction fan is placed at one end of the lower plastic sheet with a perforated duct extending at least two feet into the pile. The plastic sheets should be taped to the fan housing to minimize air leakage. Fan capacity should be 1 to 2 hp. for each 10,000 bushels, and the fan should be capable of continuous operation at ½-inch suction. Aeration fans seem adequate for this application.

The fan serves two purposes. Whenever air temperatures exceed 50° F., the fan provides suction

TABLE 17—Approximate Capacities of Rectangular Piles of High-Moisture Shelled Corn [a]

Pile Dimensions In Feet	Moisture Content, Percent			
	16	20	24	28
10 x 10	77.3	90.7	108	129
	11.6	13.6	16.2	19.4
12 x 12	134	157	187	224
	16.7	19.6	23.3	28.0
14 x 14	212	249	296	355
	22.7	26.7	31.8	38.0
16 x 16	317	371	442	530
	29.7	34.8	41.5	49.6
18 x 18	451	529	630	755
	37.6	44.1	52.5	62.9
20 x 20	619	725	864	1025
	46.4	54.4	64.8	77.6
24 x 24	1069	1254	1493	1788
	66.9	78.4	93.4	111.8

[a] Upper figures are capacities of a pile of the given dimensions. Lower figures are capacities added for each additional foot of length.

15 Andrew, F. W., "Suction-Controlled Plastic Temporary Grain Storage," Paper No. 64-557, American Society of Agricultural Engineers, 1964

to keep the plastic secure to the pile. When temperature is lower than 50° F., the end of the plastic opposite the fan is opened to allow cooling of the grain. During a normal harvest season, the pile would be closed during the day and opened for aeration at night.

Success of this practice depends on the natural occurrence of low air temperatures. Weather data for Ohio indicate the probability of such occurrence increases greatly after November 1. Length of the holding period depends on air temperatures. The plastic may be torn or punctured by a variety of hazards including children and animals. Unloading the pile by portable auger or front-end tractor loader adds one more handling operation.

Advantages of the system are greatest for large-volume producers and elevators seeking a low-cost method of increasing intake capacity. Total costs should not exceed 3 to 3½ cents per bushel including materials, operating, and handling costs. Larger volume uses have involved bunker and bin storages in volumes up to 100,000 bushels. Lower-volume producers who have their crops custom-harvested may also find considerable advantage in such a system as a means for supporting continuous harvesting.

Much of the risk of the temporary low-temperature holding method can be eliminated by assuring a supply of low-temperature air.

Refrigerated storage facilities range from converted metal bins of a few thousand-bushel capacity to complete systems of 50,000-bushel capacity with the potential of limited low-temperature drying during the cold-storage period. The prime requirement of the system is the cooling of the corn harvested daily from field temperatures to the desired storage temperature of 28° to 35° within 24 hours. Air volumes for cooling corn range from ½ to ¾ cfm per bushel.

Conventional metal bins may be converted to cold storage facilities by lining the structure with 2-inch polystyrene or polurethane sheet insulation.

At the present time, the advantages of refrigerated storage of corn appear to be only marginal for most producers and handlers. Unless the producer has a direct shipment contract with a wet-milling processor, the corn must be dried before it enters the grain trade. Investments of $1 to $1.30 per bushel capacity make such systems economically non-competitive with either oxygen-free storage or drying and storage systems for supplying livestock feed. Refrigerated systems have predicted storage time limitations of 4 to 6 months. Widespread use of such systems will depend, to a great extent, on further research and development, lower system costs, and a change in corn-marketing methods and policies.

Oxygen-Free Storage of High-Moisture Corn

The principle of preserving corn quality by limiting the oxygen in the storage environment is being used successfully in the storage of high-moisture shelled corn and ground ear corn for livestock feed. This practice is quite popular with beef cattle feeders and is gaining increased acceptance by dairymen. The feeding of high-moisture shelled corn to hogs has met with limited acceptance.

Corn is picked or field-shelled at moistures between 23 and 30 percent and is stored in conventional concrete or "gas-tight" tower silos. Rapid harvest and storage at these moisture levels help to reduce the volume of trapped air. The storage is sealed after filling. Respiration of the corn depletes the oxygen and replaces it with carbon dioxide. If the oxygen level is maintained at no more than 1 to 2 percent, further respiration and aerobic organism activity is negligible. The action of several anaerobic organisms produces a limited fermentation. The lactic and acetic acids produced by this fermentation apparently make the product very pleasing to cattle.

During most of the storage period, the corn is essentially inert. Outdoor temperature changes and solar heating of the structure cause expansion and contraction of the storage gases (primarily carbon dioxide and nitrogen). This volume change is greater for the gas-tight structures. Various devices, such as pressure-sensitive vents, breather bags, and external expansion "cells," are used to relieve pressure in gas expansion and minimize dilution of storage atmosphere with outdoor air.

The storage of high-moisture shelled corn is gaining in popularity because of the trend to field shelling and the adaptability of shelled corn to both cattle and hog feeding programs. Shelled corn gives more feed energy per cubic foot of storage and is better adapted to bottom-unloading systems. Ground ear corn preserves the bulk feed value of the cob.

High-moisture corn can be stored successfully in both conventional tower silos and in gas-tight structures. Some spoilage in top unloading is inevitable but can be minimized by selection of a silo diameter such that 2 to 4 inches of the feed are removed daily in cooler weather and 5 to 6 inches are removed in warmer weather. Both stave and monolithic (poured) concrete silos are popular. Older silos in reasonably good condition can be converted to high-moisture corn storage by carefully following manufacturers' recommondations for sealing walls and doors and installing hoops for structural strength.

Gas-tight structures usually are more expensive, but the risk of loss in storage and unloading is less than with concrete structures. Bottom unloading may proceed at any desired rate. Some problems in bottom unloading may be anticipated because of the tendency of wet grain to bridge and settle un-

TABLE 19—Approximate Silo Capacities in Standard Bushels Equivalent[a]

Kernel Moisture Content (%)	Conversion Factor	Approximate Bushels per Foot of Silo Height [b] Silo Diameter					
		10	12	14	16	18	20
SHELLED CORN [c] (1.25 cubic feet per bushel at 15.5% moisture)							
15.5	1.0	63	90	123	160	204	251
24	1.08	58	84	114	149	188	234
28	1.13	56	80	109	143	180	223
32	1.18	53	77	105	136	173	214
GROUND EAR CORN (1.94 cubic feet per bushel at 15.5% kernel moisture)							
15.5 (16)	1.0	40.5	59	79.5	103	131	162
24 (29.0)	1.11	37	53	72	93	119	146
28 (34.0)	1.16	35	50	69	89	113	140
32 (38.2)	1.21	34	48	66	86	109	134

[a] The storage volume requirement for corn increases with increasing moisture as indicated by the conversion factor in the table. A standard bushel equivalent is that volume of corn that will yield 47.3 lbs. of kernel dry matter at 15.5% moisture. To obtain standard bushels equivalent for shelled corn divide silo storage volume (3.14 x (diameter)^2 − 4) by 1.25 x conv. factor.

[b] No allowance made for compaction due to depth. Laboratory tests indicate that compaction in silos of height 40 feet or greater may allow storage capacity 10% greater than that indicated in table.

[c] For ground shelled corn, storage capacity is approximately 1.14 times that of ground ear corn of the same kernel moisture.

Source: Extension Bulletin 477, Michigan State University

evenly. SAFETY NOTE: OXYGEN IS ESSENTIAL TO HUMAN LIFE — DO NOT ENTER A GAS-TIGHT STORAGE WITHOUT FIRST ASSURING AN ADEQUATE OXYGEN SUPPLY

Oxygen-free storage renders the corn useful only for livestock feed. The product quickly goes out of condition when exposed to air. Removal and feeding during warm weather should be planned so that the high-moisture corn is consumed in a short period of time. Higher temperatures accelerate spoilage, and most feeders plan to complete removal and feeding by late spring. Shelled corn is commonly rolled, crimped, or cracked before feeding. Some operators prefer to do this processing when filling the storage. There is no evidence that breaking the kernel improves storage efficiency, so the choice of when to process is one of convenience. High-moisture corn is readily adaptable to a great variety of mechanical feeding methods.

TABLE 20—Typical Costs of Oxygen-Free Corn Storage

Type of Storage	Storage Capacity	Average Initial Cost [a]	Annual Charge [b]
	(Bushels)	. . . Per Bushel . . .	
	EAR CORN		
Conventional silo with roof	3,000	0.49	0.04
	7,000	0.43	0.04
	15,000	0.37	0.03
Airtight silo	3,000	1.15	0.10
	7,000	1.00	0.09
	15,000	0.82	0.07
	SHELLED CORN		
Conventional silo with roof	3,000	0.40	0.04
	7,000	0.35	0.03
	15,000	0.03	0.03
Airtight silo	3,000	0.90	0.08
	7,000	0.80	0.07
	15,000	0.65	0.06

[a] Includes labor and materials

[b] Ten percent of initial cost.

Source: Barre, H. J., "Points to Consider in Selecting A System for Harvesting and Handling Corn," Mimeo, Department of Agricultural Engineering, The Ohio State University, 1965.

Handling and Storage of Shelled Corn

The qualities of a good ear-corn storage previously cited are equally, or even more, important to good shelled-corn storage. The site should be well drained and so situated as to provide all-weather access and an efficient flow of traffic to and from the storage. The storage should be structurally sound and should provide adequate protection of the grain. Easy and convenient handling of the grain should be designed into the storage structures. There is, however, a trend in modern shelled-corn storage design to incorporate the storage in a complete grain and feed handling center. This trend has resulted in much greater emphasis on the methods and equipment of handling the corn as related to the storage.

Shelled corn may be stored successfully in a variety of structures including metal bins, flat storages, and converted ear corn cribs and upright silos.

Metal bins provide excellent protection for the grain, ready adaptability to mechanical handling, flexibility in the storage and handling of other grains, and relatively low storage costs. Metal bins are by far the most popular shelled-corn storages on Ohio farms. Flat storage provides low storage cost with only slightly less grain protection and handling ease and convenience than metal bins Ear-corn cribs and upright silos may be converted to shelled-corn storage if the structure is sound and so situated as to readily fit into a well-designed grain handling system. Table 21 gives typical shelled-corn storage costs.

Aeration of Shelled Corn

If shelled corn is to be stored at moistures greater than 14 percent, aeration is essential to prevent moisture migration, condensation, and spoilage during the storage period. The average air-flow rate for aerating farm-stored corn is about 0.1 cfm per bushel. The design and installation of the aeration system varies with the size and type of storage. The general scheme of aeration is to lower the temperature of the corn in the fall, hold at low temperatures during the winter, and raise the temperature in the spring. This means that aeration should occur with significant trends in either decline or rise of outdoor temperatures with periodic operation during the winter as a safeguard against accumulation of moisture and heat in the corn. A prime requirement of an aeration system is that air be exhausted outside the bin. Most aeration systems are downflow-exhaust systems simply because of the ease of equipment installation.[16] Cost of aeration is usually less than 1 cent per bushel.

TABLE 21—Typical Shelled-Corn Storage Costs

Type of Storage	Storage Capacity (bu)	Average Initial Cost [a]	Annual Charge [b]
Grain Bin	3,000	0.35	0.03
	7,000	0.30	0.03
	15,000	0.25	0.02
Flat Storage	20,000 plus	0.25	0.02

[a] Includes labor and materials.

[b] Ten percent of initial cost.

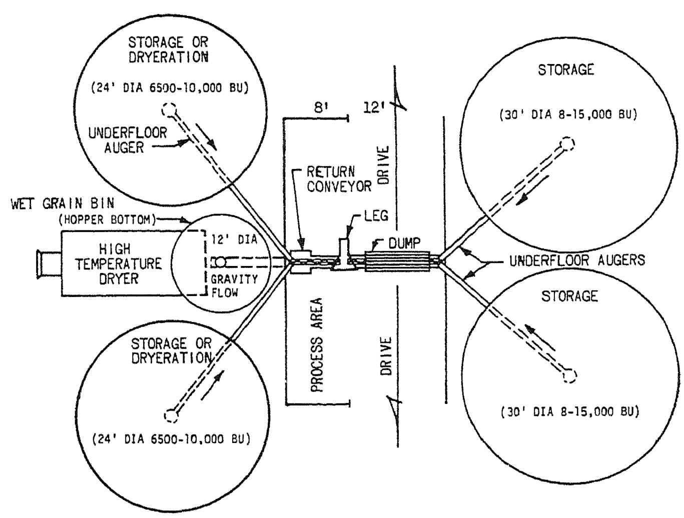
Source: Barre, H. J., "Points to Consider in Selecting a System for Harvesting and Handling Corn," Mimeo, Department of Agricultural Engineering, The Ohio State University, 1966.

Handling Shelled Corn

The trend in design of shelled-corn storage and handling systems toward grain handling centers creates greater demand for design and layout of totally-integrated systems with efficient matching of both function and capacity of the individual components. Figure 13 shows the design pattern for a grain handling center which may start with bin drying and portable auger conveying, and later be developed into a complete grain drying, handling, and storage center with vertical cup elevator (leg), work shelter, and provision for feed processing. Such planning allows a farmer to build an efficient and flexible system to meet his grain handling needs as resources permit.

[16] More detailed information on design and operation of aeration systems is given in Circular 849, "Aerating Farm Stored Grain," College of Agriculture, University of Illinois.

FIGURE 13—Typical Layout of Shelled-Corn Storage and Handling Systems



Source: Extension Bulletin AE-72, "Dryeration," Purdue University.

SECTION 3. MANAGEMENT CONSIDERATIONS

By R. DONALD MOORE, area agent, farm management, Eaton Area Extension Center

In light of what is happening in the corn industry in Ohio and the entire Corn Belt, it is important that each farm decision-maker use the best information available when making an analysis of his best response to the many changes. In Section 1 and 2, the marketing aspects of the corn crop and the engineering principles on harvesting and conditioning are discussed. Some additional farm business management factors that should be considered are:

1. The different risks involved with the various investments. These could include the risk of your age, the ease and ability to resell your investment, and others.
2. Invest your money where it will give you a desirable return.
3. Consider the costs, both overhead and variable, that will be incurred and the benefits derived from the new move.
4. Compare the costs and benefits of how you are handling your corn crop now with your proposed plans. Do it on paper. What are your long-time marketing plans?

The next several pages should be a guide to you in your final decision as to the harvesting, conditioning, and marketing of your present and future corn crops.

How Are You Harvesting Corn Now? Start There!

Ohio farmers are now harvesting corn by many methods — from husking by hand to picking and field shelling with high-capacity, self-propelled combines. You are somewhere within this range of methods. The methods you are now using may be ideal for your situation. There may have been drastic changes in your situation, however, since you chose the methods you are now using. In making an economic analysis of your own situation, start evaluating at the point where you are now. Compare alternative methods with the method or system you are now using or one with which you are familiar. By this approach, you can avoid the mistake of making a change not suited to your situation or changing simply for the sake of "making a change." The innovative farmer is not always correct in his analysis and decision to follow new methods, even though he may be first. So make decisions with all the known facts and ideas that are available.

Any change in your methods of harvesting, conditioning, storing, or marketing the crop should be based on expectations that you will be able to do one or more of these:

1. Reduce the per bushel cost of producing and handling the crop.
2. Improve the performance of the whole farm business operation without increasing the costs per bushel of output.
3. Improve the quality of the crop so a better quality product will be marketed.
4. Improve your pricing and selling strategy.

Change May Not Mean New Investment

If you can improve your profits without increasing your investments, then this is your first and best move to make. By doing this, you will have improved the returns on your present investments. A good example of this, as illustrated in Section 1, is to consider establishing the price of your crop through futures trading before it is harvested and at a time of your own choice — not necessarily at harvest time.

Another example would be to consider custom harvesting or custom drying, where the investment has been made by someone else, and you are simply paying for a service rendered. By keeping abreast of better hybrids, fertilizers, pesticides, and techniques wherever they can contribute to additional output with little or no additional input. In these ways you can produce more total product with a little or no additional investment.

Marketing Plans Can Influence Harvesting and Handling Processes

The cash-crop farmer has different considerations in handling his corn crop than the livestock producer, who plans to market the crop through his livestock. Various alternatives apply to different situations, and each alternative should be evaluated with respect to the different methods of selling the corn crop from the farm. Some important alternatives include:

1. Selling either ear corn or shelled corn at harvest time
2. Drying and storing shelled corn off the farm for later sale.
3. Drying and storing shelled corn on the farm for later sale or for feeding to livestock.

4. Drying shelled corn on the farm but storing off the farm.
5. Storing high-moisture shelled corn in gas-tight silos for livestock feed.
6. Storing ear corn in cribs on the farm and using forced-air drying to condition for either sale or feed.
7. Storing ensiled high-moisture ground ear corn in tight-walled silos for cattle feed.

Although there are other harvesting alternatives, the above seven choices describe most situations in Ohio. You may be in the situation where you have ear-corn storage that is inadequate and have a worn-out picker. You may need to make an investment decision. The most logical steps to take are first to analyze your present operation, second to study your present and future marketing alternatives, and third to compare costs and returns under the alternative plans with your present system — then make your move.

You have two major alternatives in marketing your corn crop. Those choices are to sell as cash grain or to sell your corn through your livestock, or a combination of both marketing choices. In many situations, you have a different material-handling problem if you are going to sell corn for cash than if you plan to sell your corn through your livestock. The problem of saving the cob is of different importance in each marketing situation.

An Ohio farmer marketing his corn crop may find himself in one of several common situations. These include selling for cash and feeding to hogs, dairy, cattle, fat cattle, lambs, and poultry. Some of these we will illustrate further.

Cash-Crop Farmer Situation

If you are a cash crop farmer, you have a choice of harvesting as ear corn or shelled corn. If you harvest **EAR CORN**, in most seasons, your best choice is to store it on the farm, dry it with natural drying and sell it at a later time. You should investigate improved materials handling and storing ideas along with forced ventilation for your system to make sure that you can effectively handle and store your corn crop. You may want to be able to adapt for heated air if an emergency occurs. Heated-air drying of ear corn also increases drying capacity. Then you have the alternative of selling either ear corn or high quality shelled corn. This marketing can be done during off-peak labor seasons.

You have the advantage of changing your mind if you wish to feed livestock, since you will have a high-quality product for feed. Some disadvantages of this system may be limited capacity of the harvesting machine you use and more materials to be handled at the harvest time.

One choice you have for **SHELLED CORN** is to haul it off the farm directly from the harvesting machine and to sell it as shelled corn. Another choice is to dry it on the farm at harvest time and sell the dried shelled corn. A third choice is to dry it on the farm at harvest time and store it off the farm for later sale. Still a fourth choice is to dry and store it on the farm for later sale.

You also should understand how futures-contract selling of corn may be useful to you when considering the above alternatives. After you thoroughly investigate and understand commodity futures, you may wish to sell your corn prior to harvest. (See explanation of this procedure in Section 1.) This alternative can eliminate your storage costs and permit you to market your crop at a price you had chosen prior to harvest season.

If you feed part or all of your corn crop to livestock, you have some additional alternatives in how to harvest and store your corn crop besides dry shelled corn and dry ear corn. These additional choices include ensiled, high-moisture shelled corn fed to hogs, lambs, and cattle; and ensiled, high-moisture ear corn for cattle and dairy feed.

Hog Farmer Situation

If you are a hog farmer, your choices include harvesting as ear corn or shelled corn. If you harvest ear corn, refer to the statements on ear corn in the case of the Cash-Crop Farmer Situation. If you harvest shelled corn, your most likely choices will be drying and storing on the farm or storing high-moisture shelled corn in gas-tight silos.

The advantage of drying and storing on the farm includes the chance to mix different rations for your various groups of hogs. You also will have a salable porduct if you wish to reduce your swine enterprise or change your long-time plans. The disadvantages in this system are drying costs and possible limited drying capacity at harvest time.

Major advantages of high-moisture shelled corn stored in gas-tight silos are (1) you have a good quality feed which is readily eaten by market hogs, (2) there are no drying costs, and (3) since the product requires no drying, you have no drying capacity limitations.

The disadvantages of high-moisture shelled corn are (1) limited sale of the product if you change your mind, (2) some weight ranges of pigs may not adjust readily to the high-moisture corn and (3) more demanding management capabilities are required in storing and feeding of the product.

Beef Cattle Feeder Situation

If you expect to be in the cattle feeding business over a long period, your best choice likely is high-moisture ground ear corn stored in tight-walled silos. You will experience a better dry matter conversion from this product than from dry corn. You will have a product that is ready to feed at any time throughout the year and your labor costs should be minimized. High-moisture ground ear corn is a very palatable cattle feed.

The major disadvantage of high moisture ground ear corn is that you are almost compelled to feed the product to cattle in order to market it. Care should be exercised to make sure that enough corn is feed off each day to reduce unnecessary spoilage.

If you desire more flexibility in your operation, dry ear corn also is a very acceptable feed for cattle. With dry ear corn, you have a choice of selling corn as a cash crop or feeding it to cattle. As a cattle feed, however, dry ear corn has a lower feed conversion rate than high-moisture ground ear corn and you possibly will experience higher labor and materials handling costs.

If you wish to consider shelled corn for cattle, you may choose either high-moisture shelled corn or dry shelled corn. Both of these alternatives are especially good if you are a heavy silage feeder. High-moisture shelled corn is a very palatable cattle feed.

The cost of feeding shelled corn with supplement may be too high to permit you to feed this ration to cattle profitably.

Dairyman Situation

If you are a dairyman, you have available all the alternatives of the hog farmer and cattle feeder. High-moisture ground ear corn is a very acceptable feed for dairy cows. If your long-term plans involve an intensified dairy operation, this may be your best corn handling choice. Your other alternatives fit very well the situation of the cattle feeder.

Consider Costs in Long-Time Investment Decisions

As you use the information in this publication in analyzing the best solution to your corn handling problems, you will need to apply several business management principles and methods. Since many of the systems described in Sections 1 and 2 and involved in the above examples require large outlays of capital, you especially need to realize the relationships between capital investment and the costs per bushel of corn you handle. To overlook this important relationship is to invite serious difficulty in meeting competitive conditions which exist now and are sure to exist in future years. For one thing, when you have invested in a permanent installation, your farm business must bear the cost of owning this capital asset regardless of the value you receive from it. Thus the annual overhead or fixed costs created by a high-cost installation may be a factor that spells disaster rather than success to your farming business. For example, a recent Indiana study of 30 farms revealed that fixed or overhead costs amounted to 83 percent of the total costs of drying grain, whereas the operating costs were only 17 percent of this total.[16]

6 An Economic Analysis of Drying Wheat and Corn on Indiana Farms, Bulletin 630, Indiana Agricultural Experiment Station in Cooperation with Farmers Cooperative Service and Agricultural Marketing Service, U.S.D.A., July 1955.

Understand Overhead Costs

The costs that go into the handling and marketing of corn are divided into overhead (or fixed) costs and variable costs. Overhead costs are essentially investment costs and include depreciation, interest, repairs, taxes, and insurance. Normally these are increased when capital is added to the business. One way you can reduce the actual amount of overhead costs is by reducing your capital investment. These costs can be reduced on a per-unit basis, however, by spreading them over a greater volume. A good procedure in estimating annual overhead costs for corn storage faciilties and equipment is to take a percentage of the purchase price and project it as annual costs.

How Volume of Business Influences Overhead Costs

It is important to understand the relationship of overhead costs to the volume of business. The amount of this cost remains the same, regardless of the number of bushels conditioned and stored. However, as you can see in Table XX and in Figure 12, the overhead costs are reduced on a per-bushel basis as the volume of corn handled is increased.

The overhead costs, as used in this illustration, are based on a $10,000 investment of which 15 percent, or $1,500, is the annual fixed or overhead cost.

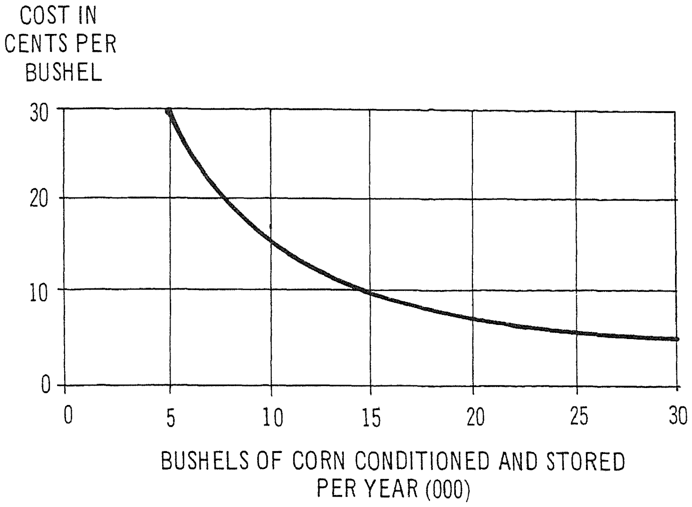
In this example, you can see that there is an annual $1,500 overhead cost on the buildings and equipment which will be charged against the enterprise regardless of the amount of corn handled after the investment has been made.

TABLE 18—How the Annual Overhead Costs per Bushel on a $10,000 Drying and Storage Facility Decreases as Volume Increases

Bushels of Corn Conditioned and Stored Annually	Annual Overhead Cost per Bushel
5,000	30.0
10,000	15.0
15,000	10.0
20,000	7.5
25,000	6.0
30,000	5.0

To attain low overhead costs on a per-bushel basis, it is necessary to attain high volume through your conditioning and storage system. This is the best way to reduce overhead costs per bushel. The only other way is to invest less capital in the corn-handling facility and equipment. These facts indicate the importance of using good judgment on the initial investment.

FIGURE 14—Annual Overhead Costs per Bushel on the $10,000 Proposed Drying and Storage Facility (As Illustrated in Table XX)



Consider All Costs and Benefits

A business management method useful to you in evaluating your best choice for a corn-handling system is the partial budget.

The simplest way to organize a partial budget is to list, on one side, the added costs with the reduced incomes (if any) and to list on the other side the added income with the reduced expenses (if any). By this process, you can always compare your proposed investment with your present operation and with all other alternatives to the extent that you have costs and benefits to compare. This should enable you to make the best choice among the various alternatives.

Consider Taxes on the Investment

The choice of equipment you purchase also may be influenced by the kind and the amount of taxes assessed against it. Since the passage of House Bill No. 480 by the Ohio General Assembly, personal property taxes on items used for agricultural production are being reduced and eventually will be eliminated. Corn storage, in most instances, is in facilities that are considered as real property and are taxed accordingly. You may want to consult your county taxing authorities to determine which components of a corn conditioning and storage system are considered by them as real property and which components are considered as personal property.

Conclusion

No one method of harvesting, storing, and marketing corn is best for all farmers. The technological changes in the corn industry, both on the farm and in the marketing channels, that have taken place in the last decade should make the farm decision-maker very cautious of long-term improvements that do not lend themselves to flexibility. Along with this, he should expect any new imvestment to return all costs in a relatively short time because of the changing nature or farming in recent years.

HELPFUL PUBLICATIONS

These publication provide additional information about corn production, harvesting, handling, or marketing.

Available from Ohio Cooperative Extension Service offices

Bul. 468, *Grain Transportation in Ohio*

Bul. 425, *How to Determine Shrinkage in Grain*

Bul 472, *The Ohio Agronomy Guide*

MM-275, *An Economic Analysis of Corn Harvest and Storage Systems for Ohio Farmers* Card, *How to Measure Corn Harvesting Losses*

USDA Farmers' Bul. 1976, *Handling and Storing Soft Corn on the Farm*

USDA Farmers' Bul. 2214, *Drying Shelled Corn and Small Grains*

USDA Miscellaneous Bul. 919, *Drying Ear Corn by Mechanical Ventilation*

Available from Other Sources

Bul. AE-67, *Selecting a Grain Drying Method,* Cooperative Extension Service, Purdue University

Bul. AE-72, *Dryeration, Better Corn Quality with High Speed Drying,* Cooperative Extension Service, Purdue University

Cir. 916, *Drying Shelled Corn,* Cooperative Extension Service, University of Illinois